AUSTRALIAN AND NEW ZEALAND GEOMORPHOLOGY GROUP

7TH MEETING

JAMES COOK UNIVERSITY OF NORTH QUEENSLAND

CAIRNS

OUTLINE OF PROGRAM AND ABSTRACTS

1996

Welcome to the 7th Australian and New Zealand Geomorphology Group Conference. The conference is as popular as ever and I certainly hope that this meeting is as successful as all of the previous meetings of our group. I have tried to stay with our 'traditional' format and have avoided concurrent sessions. We have a very full program with around 20 papers per day. In order to have this many presentations I suggest that talks be restricted to 15 minutes plus 5 minutes for questions. Also, as you will see, the morning sessions have up to six talks before we break for morning tea. This is intense but is necessary at some time during each day; I thought that the mornings when we are hopefully rested and fresh is the best time to have the large sessions. The program is designed so that each session is somewhat thematic but with considerable variation between sessions on each day.

I would like to thank Colin Pain, Mike Craig and John Webb for their assistance with organising and particularly running the post-conference excursion. Thanks also go to Gerald Nanson for his advice at various times.

I am grateful to CRC LEME for donating funds for Colin Pain and Mike Craig to fly to Cairns last year to begin preparing for the post-conference excursion. I have included their logo below.

I hope you enjoy both the conference and your stay in Cairns.

Jon Nott
Cairns campus
James Cook University

The seventh meeting of the Australian and New Zealand Geomorphology Conference has been partly sponsored by

CRCLEME

Cooperative Research Centre for
Landscape Evolution & Mineral Exploration

MONDAY 30th SEPTEMBER

Coastal evolution and processes - northeast Queensland

9:00 Introduction - J. Nott

9:10 K. J. Woolfe, P. Larcombe & R. G. Purdon
Plotting the first-order controls on geomorphology and sedimentary architecture

9:30 P. Larcombe, K. J. Woolfe & A. R. Costen
Hydrodynamic, sedimentary and sea-level controls on Holocene reef initiation on the Great Barrier Reef, Australia

9:50 K. Woolfe, P. Larcombe & A. R. Orpin
Modern analogues may explain the evolution of ancient river systems on the Great Barrier Reef continental shelf

10:10 S. Bryce, P. Larcombe & P. V. Ridd
Sedimentary facies of tropical estuaries: A case study - The Normanby River, northeast Australia

10:30 M. Hayne
Northeast Australian cyclonic variability during the late Holocene

MORNING TEA

Fluvial

Session Co-ordinator - Gerald Nanson

11:10 K. Fryirs
The character and age structure of valley fills in upper Wolumla Creek catchment, south coast, NSW

11:30 A. Brooks
Riparian vegetation as a control on hydraulic geometry and channel evolution in a natural river system - Thurra River, East Gippsland

11:50 J. D. Jansen, G. J. Brierley & P. C. Fanning
Riffle-pool morphodynamics - an 1800 year history of cut and fill along an arid upland valley

12:10 R. Purdon & K. J. Woolfe
Stranded terraces in the TVZ: Deposits of a rapidly eroding meandering river

LUNCH

Dating and palaeoenvironments

Session Co-ordinator - James Shulmeister

1:10 D. Fink
Surface exposure histories using in-situ cosmogenic radio-isotopes and AMS: Applications to the Australian scene

1:30 D. Fabel & J. Stone

Cosmogenic isotopes as a geomorphological tool - some lessons and potential future uses

1:50 B. Pillans & E. Tonui

Palaeomagnetic dating of weathered regolith at North Parkes mine, NSW

2:10 D. B. Gore & E. A. Colhoun

Regional contrasts in weathering, glacial sediments and terrain suggests long term subaerial exposure of the Vestfold Hills, East Antartica

2:30 D. Hannan, D. Fink, M. Frith & C. Tuniz

Dating glacial events on the central plateau, Tasmania

AFTERNOON TEA

Landslides and Karst

Session Co-ordinator - Brad Pillans

3:10 M. J. Crozier

Changes in terrain resistance to landsliding following erosion events: Concepts and methodology

3:30 T. Glade

Occurrence of rainfall - triggered landslides in relation to rainstorms in New Zealand

3:50 M. J. Page

Relationship between landslide frequency and strom rainfall in Waipaoa catchment, east coast, New Zealand

4:10 N. J. Preston

Event - induced changes in landsurface condition - implications for catchment stability

4:30 F. Ahnert & P. Williams

Modelling tropical humid karst landforms

4:50 S. White

Karst of the Cainozoic limestones of the Otway Basin

TUESDAY 1st OCTOBER

Coastal

Session Co-ordinator - Piers Larcombe

8.40 R. Hindson
An investigation of the geological trace of the tsunami generated by the 1755 "Lisbon" earthquake

9:00 E. A. Bryant, R. W. Young, D. M. Price & D. J. Wheeler
The magnitude and frequency of tsunami: south coast of New South Wales

9:20 J. Nott
High energy wave deposits inside the Great Barrier Reef: Determining the cause - tropical cyclone or tsunami

9:50 J. R. Goff
Shaken and stirred: The effects of marine transgression, European colonisation and earthquakes on coastal sedimentation

10:10
M. J. Shepherd
The development of New Zealand's largest barrier island: Matakana Island, Bay of Plenty

10:30 J. Shulmeister and J. M. Soons
Preliminary results of a late Quaternary drilling project, Canterbury, New Zealand

MORNING TEA

Fluvial

Session Co-ordinator - Gary Brierley

11:10 K. Banbury, B. Gomez & P. Hosking
Bed-level changes in Te Weraroa Stream, East Cape, New Zealand

11:30 B. Rosser, B. Gomez & J. Palmer
Bed material characteristics of the Waipaoa River, East Cape region, New Zealand

11:50 R. Wende
Ridge-forming anabranching rivers: Examples from the Kimberley, Western Australia

12:10 S. Tooth
Anabranching channel systems of arid central Australia: The role of tributary inputs

12:30 J. Woodfull
Downstream decreasing channel capacity streams in Australia: Increasing our awareness and understanding of this phenomenon

LUNCH & GENERAL MEETING

Quaternary Environments

Session Co-ordinator - Paul Williams

1:50 J. Chappell, B. Dietrich & G. Day
The effect of post-glacial base level changes on the morphodynamics of large meandering tropical rivers in Papua New Guinea

2:10 M. Williams, B. Cock, J. Prestcott & D. Adamson
Quaternary fluviatile, lacustrine and aeolian sedimentation in the Flinders Ranges, South Australia: A preliminary report

2:30 A. Fried
A geomorphic record of climate change during the last glacial cycle from the Condobolin area, central New South Wales

2:50 A. J. Dare-Edwards, K. J. Page, J. Owens, S. Chavangklang & D. Price
Source bordering dunes of the Wagga Wagga area, New South Wales; chronology and stratigraphy

3:10 M. E. Longmore & G. H. McTainsh
Dust records in the Pleistocene sediments of Fraser Island; palaeoclimatic reconstruction of wind erosion over the last 400 ka

AFTERNOON TEA

Landscape development

Session Co-ordinator - Colin Pain

3:50 P. Fanning
Recent landscape evolution in western NSW

4:10 S. M. Hill, G. Taylor & R. A. Eggleton
A re-evaluation of the stratigraphic significance of duricrust inter-relationships in the Broken Hill region, western New South Wales

4:30 B. Bourman
Land surfaces and 'laterites' in southern South Australia

4:50 L. Bakker, D. J. Lowe & M. J. Selby
Towards a model of landform development on an Ignimbrite Terrain: Mamaku Plateau, New Zealand

THURSDAY 3rd OCTOBER

East Australian Highlands

Session Co-ordinator - Robert Wray

8:40 P. W. Whitehead & P. J. Stephenson
Lava inflation landforms in the Toomba and Undara basalt flows, North Queensland

9:00 J. A. Webb, S. Marshallsea & P. F. Green
The thermal history of the Laura Basin, North Queensland, and the implications for denudation of the region

9:20 C. D. Ollier & C. F. Pain
Evidence for downwarping on passive margins

9:50 M. Orr
Geomorphic expression of fault block movement in the highlands of Eastern Victoria

10:10 M. J. Spry & D. L. Gibson
Basalt and sub-basaltic sediments in the Clyde River valley, NSW

10:30 R. S. Abell
Geomorphological evolution of the Lake Bathurst drainage basin, New South Wales

MORNING TEA

Plenary Speech

11:10 D. Hopley
Reef Islands and global climate change

Historical stream changes

Session Co-ordinator - Andrew Brooks

11:40 S. O. Brizga
Historical channel changes on the major rivers of north-eastern Queensland

12:00 I. Prosser
Thresholds of channel initiation in historical and Holocene times, southeastern Australia

12:20 I. Reinfelds
Mander cutoffs as indicators of environmental change, LaTrobe River, Victoria

12:40 G. J. Brierley
European impacts on downstream sediment transfer in Cabargo catchment, New South Wales

LUNCH

Historical channel changes continued

1:40 B. Starr
The timing, extent and causes of post-European landscape erosion in the upper Murrumbidgee catchment in New South Wales

2:00 M. J. Tulau
The original forests revisited - the role of geomorphology

Aeolian landforms and processes

Session Co-ordinator - Tony Dare-Edwards

2:20 M. A. Bishop
Morphology of the Gurra Gurra cresentic dunes, Strzelecki Desert, South Australia

2:40 G. McTainsh, W. Nickling, J. Leys & A. Lynch
Wind erosion rates in the Channel Country of Western Queensland

3:00 D. Jackson
High resolution aeolian sand transport measurement in natural conditions

AFTERNOON TEA

Mine site rehabilitation

Session Co-ordinator - ~~Sandra Brizga~~ Colin Pain

3:40 B. Kirsch, M. Short & T. Baumgartl Andrew Grabski +
Erosion, vegetation and landform development on reclaimed areas of open cut coal mines in Queensland

4:00 G. J. Sheridan, C. Carroll, B. H. Kirsch & H. B. So Gary
Determination of the contribution of rill and interill processes to the erosion of reclaimed open-cut coal mining landscapes

4:20 M. F. Short, B. H. Kirsch, G. Sheridan & H. B. So Michael.
Depressional salt accumulations on rehabilitated open-cut coal landscapes in the Bowen Basin, Queensland

4:40 M. J. Saynor & K. G. Evans
The effect of vegetation and surface ripping on erosion and hydrology of the Ranger uranium mine, waste rock dump

FRIDAY 4th OCTOBER

Fluvial

Session Co-ordinator - Ivars Reinfelds

8:40 D. Sinai & P. Hesse
Magnetic sourcing of bedload in Wolumla Ck catchment, south coast, NSW

9:00 M. Soufi & I. P. Prosser
Gully development in the Kapunda Forest, southeast NSW, Australia

9:20 A. W. Raine & S. J. Curtis
Trialling low cost options for river restoration: Nambucca River, NSW

9:50 C. Purtle, T. Dawson & D. Outhet
Managing accelerated channel change: Taylors Creek, NSW

10:10 I. McCarthy
From research to reality - Rivercare!

10:30 W. D. Erskine, J. Sammut, J. W. Tilleard, R. F. Warner & K. F. Shanahan
Use of trial releases for the prediction of the biogeomorphic impacts of interbasin water transfers

MORNING TEA

Palaoefloods

Session Co-ordinator - Martin Williams

11:10 I. D. Rutherfurd, P. Bishop, G. Goldrick & A. Fried
Palaeoflood deposits in the Lachlan Gorge: Implications for the terrace and floodplain formation, and the flood record

11:30 M. C. Bourke
The geomorphic effects and chronology of extreme flood events in Central Australia

11:50 L. Grotaers
The Buchan caves gravels: Implications for past depositional environments

12:10 R. A. L. Wray
The morphology and genesis of drainage runnels on the Sydney Basin quartz sandstones

LUNCH

Coastal

Session Co-ordinator - Ted Bryant

1:10 J. M. Soons
Changing places - recent coastal change on Banks Peninsula

1:30 D. M. Kennedy & C. D. Woodroffe
Lagoonal sedimentation on Lord Howe Island

1:50 B. P. Brook, C. D. Woodroffe, C. V. Murray-Wallace, E. A. Bryant & D. M. Price
Late Quaternary carbonate sedimentation on Lord Howe Island

Landscapes

Session Co-ordinator - Jon Nott

2:10 L. M. Reid, N. A. Trustrum, P. G. Luckman & M. Marden
The Waipaoa: A geomorphic perspective for assessing environmental change on the large catchment scale

2:30 G. Hancock & G. Willgoose
Experimental testing of a landform evolution model

2:50 B. P. Ruxton
A sequence of rainforest fires in Feral Mountains of Papua New Guinea

MONDAY 30TH SEPTEMBER

PLOTTING THE FIRST-ORDER CONTROLS ON GEOMORPHOLOGY AND SEDIMENTARY ARCHITECTURE

Ken J. Woolfe, Piers Larcombe and Richard G. Purdon
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Fortunately for geomorphologists the surface of the globe is not uniform. A plethora of surficial processes deposit and erode material differentially, giving rise to a diversity of facies, surficial forms and sedimentary architectures. While much effort has been focused towards understanding form-process associations of modern and ancient environments, relatively little attention has been given to the differential rates of deposition and erosion which provide the primary controls on geomorphology and sedimentary architecture. Two examples of this type of control are outlined below:

1) It has recently been demonstrated that by plotting the rate of channel deposition (dc/dt) against the rate of interchannel deposition (df/dt) a series of eight broad fields of channel style can be defined (Fig. 1) (Woolfe and Purdon, 1996; Woolfe and Balzary, in press). Such a diagram accommodates all possible channel-interchannel relationships and facilitates the prediction of first-order geometries and preservation potentials without the need to pigeonhole systems into inappropriate boxes.

Fig. 1. Channel Fields, *a framework diagram for the spectrum of channel style.*

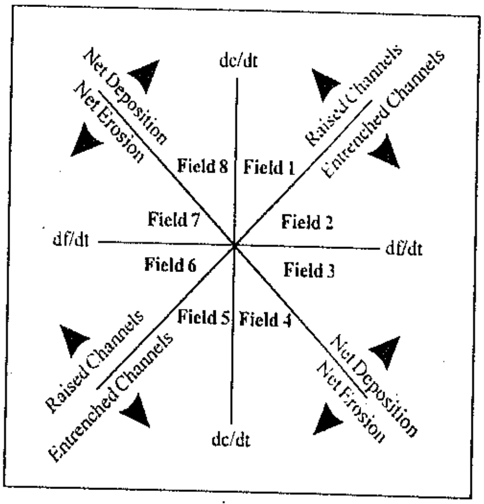
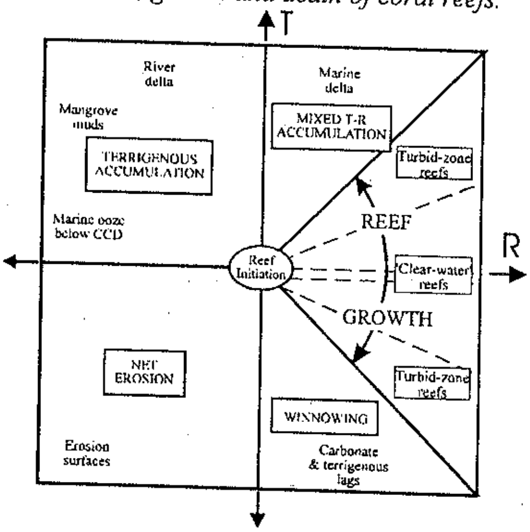


Fig. 2 Coral Fields, *conceptual framework for the birth, growth and death of coral reefs.*



2) By applying a similar approach to coral reefs, using the relative rates of reefal carbonate (R) and non-carbonate (T) erosion and/or deposition (Fig. 2), it is possible to define environmental regimes which lead to the birth, survival and death of coralline reef structures (Larcombe and Woolfe, subm).

Using this approach it is thus possible to place all channelised systems into a continuum of style. Further, the presence of new reefs in regions of the Great Barrier Reef (which were traditionally considered unsuitable for reef growth) can be explained on the basis of differential rates of erosion and deposition (Larcombe and Woolfe, this volume).

References

Larcombe, P. & Woolfe, K. J. (subm.) Hydrodynamic, sedimentary and sea-level controls on the distribution of Holocene inner-shelf coral reefs, Great Barrier Reef, Australia. *Marine Geology.*

Woolfe, K. J. & Balzary, J. R. (in press) Fields in the spectrum of channel style. *Sedimentology.*

Woolfe, K. J. & Purdon, R. G. (1996) The deposits of a rapidly eroding meandering river: Terrace cut and fill in the Taupo Volcanic zone. *New Zealand Journal of Geology and Geophysics 39,* 243-249.

Hydrodynamic, Sedimentary and Sea-Level Controls on Holocene Reef Initiation on The Great Barrier Reef, Australia

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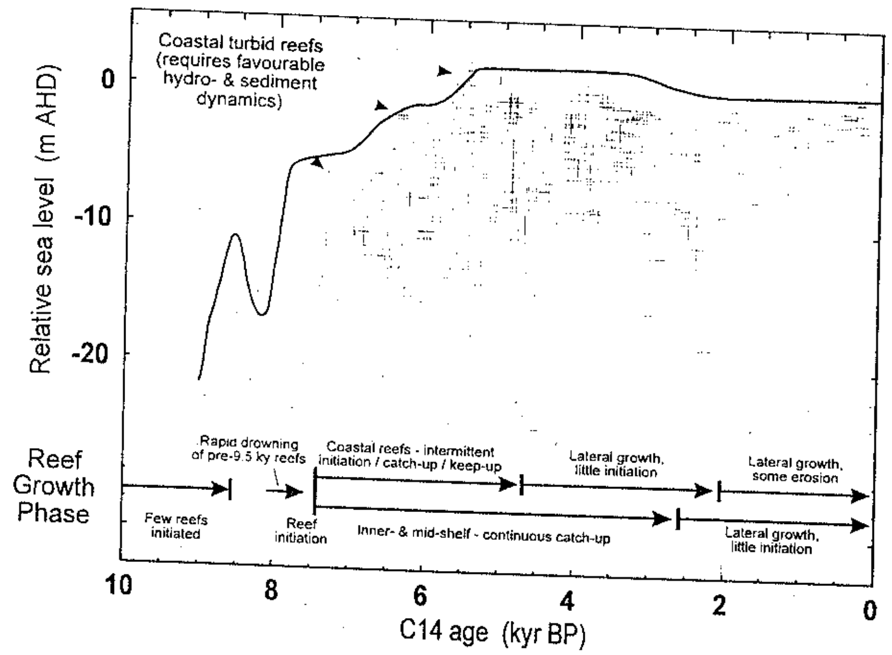
The post-glacial development of the Great Barrier Reef (GBR) and its modern environments are important geological and environmental issues. Data from inner-shelf coral reefs near Townsville show that living reefs occur in turbid conditions in water depths of less than 4 m. Water turbidity is driven by wave-induced resuspension, and turbidities are sometimes over 100 NTU. This is well above previously published coral 'thresholds'. The studied reefs are influenced by longshore wind-driven currents on linear shorelines (e.g. Halifax Bay), and by eddying processes on irregular coastlines (e.g. Magnetic Island). These processes cause long-term sediment accumulation to be zero or negligible, so that in sufficiently shallow water, with favourable hydrodynamics and sediment dynamics, 'coastal turbid reefs' are able to flourish.



In the diagram, coral sample elevations and radiocarbon ages from the central GBR shelf (sources in Larcombe & Woolfe, in prep.) have been superimposed upon the sea-level curve of Larcombe et al. (1995). With episodic sea-level rise, the relationship between the elevation of living corals and sea level will be temporally variable. Coastal turbid reefs may be related to the episodic nature of sea-level rise (SLR). These reefs have probably undergone episodic cycles of initiation and growth; the former induced by the development of newly available substrates following episodes of rapid SLR, and the latter occurring during the stillstand or period of slower SLR.

Close to the Burdekin River, (the main regional Holocene sediment source), the inner-shelf terrigenous sediment wedges are shore-connected (Bowling Green Bay & Cleveland Bay). Further downdrift, nearshore sediment accumulation is zero and the wedge is not shore-connected (Halifax Bay), which has allowed corals to initiate growth upon exposed lag Pleistocene gravels. The presence and extent of transgressive inner-shelf sediment bodies provide an explanation for the 500-800 year lag in coral initiation after drowning of the substrate by SLR. Nearshore sediment accumulation buries potential sites of reef initiation and any existing coastal turbid reefs to landward.

MODERN ANALOGUES MAY EXPLAIN THE EVOLUTION OF ANCIENT RIVER SYSTEMS ON THE GREAT BARRIER REEF CONTINENTAL SHELF

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Today along the North Queensland coastline there are several major river systems entering the Great Barrier Reef lagoon. Above the tidal limit most coastal plain rivers are depositional, both in their floodplain and channel. Erosional river characteristics are typically absent. Below the tidal limit channel geomorphology changes dramatically, with deeply incised mangrove-fringed channels. However, these systems are still depositional because vertical flood-plain accumulation volumetrically exceeds channel floor erosion. Beyond the front of the ebb tide delta, channels lose their identity on the inner-shelf within a few tens or hundreds of metres of the mouth. The key feature is that channel incision is limited to the intertidal zone.

Many ancient channel systems can be seen in seismic sections and have been sampled in subsurface cores from the Great Barrier Reef shelf. These channels formed during times of glacially lowered sea level, and many authors have envisaged major river channels extending from the ancient river mouths across the middle and outer-shelf. Within the modern inner-shelf embayments a multitude of buried channels exist. If the behaviour of modern deltas is used as a model, it is unlikely that a single continuous incised channel existed across the shelf for significant periods of time. Most of the channel fills have been interpreted to be transgressive backfill deposits, commonly mangrove estuarine. Stranded transgressive prodelta lobes have been described by other workers on the middle-shelf using high resolution seismics. Rapid episodic rises in sea level have been interpreted to be responsible for their preservation. Significant volumes of low stand alluvial sediment have presumably been reworked landward from the middle-shelf and incorporated into the modern terrigenous coastal wedge.

Due to the low gradient of the inner and middle-shelf, during periods of lowered sea level the stream power of rivers was probably small, resulting in net deposition (also indicated by drill hole data). This would have led to the development of straight or anastomosing channels with little down-cutting except in their estuarine reaches and proximal to the shelf break.

It is suggested that the ancient channels in the Great Barrier Reef lagoon then the ancient channels must have been intimately associated with intertidal systems and are not the product of shelf wide fluvial down-cutting.

SEDIMENTARY FACIES OF TROPICAL ESTUARIES: A CASE STUDY: THE NORMANBY RIVER, NORTHEAST AUSTRALIA.

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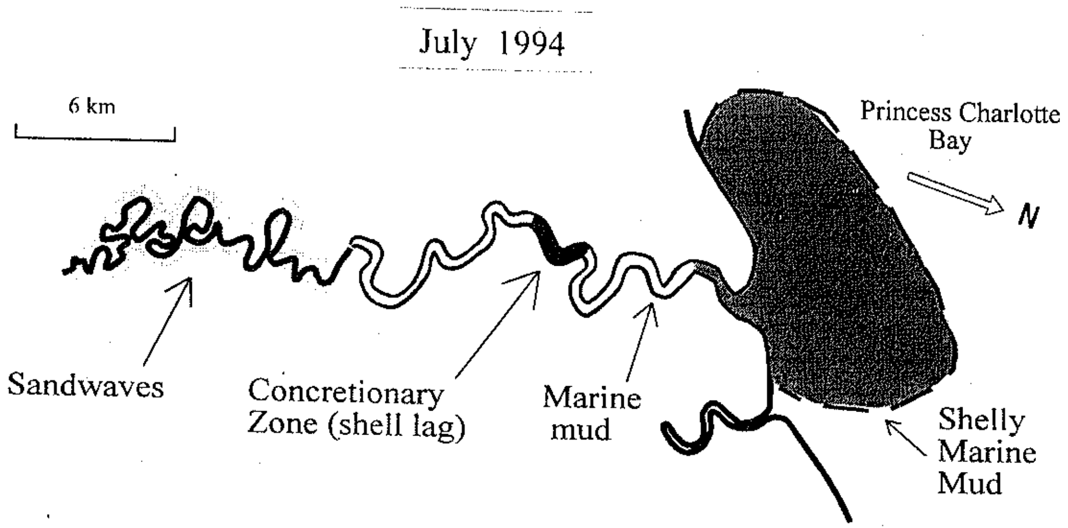
Most of the northern coastline of Australia contains estuarine and coastal systems which are dominated by mangroves, yet little is known of the sediment transport processes within them. The Normanby River, tidally influenced for over 50 km, is fringed by a 0-10 m wide strip of mangroves and surrounded by expansive salt flats. It has a catchment area of 24 500 km^2 and is thought to be the largest sediment-contributing river in the far northern sector of the Great Barrier Reef lagoon, with an annual sediment discharge of ca. 7500 m^3 (Belperio, 1983).

Three weeks of continuous tidal current and suspended-load data measured during the dry season (at both the mouth and 20 km up-river) shows that flood tides are dominant, reaching speeds of up to 1 ms^{-1}. Surface and near-bed suspended sediment concentrations reach up to 400 mgL^{-1} on the flood tide and at high water, and net sediment fluxes are probably landward. 3.5 kHz seismic data, echo-sounding profiles, grabs and vibrocores from the river bed reveal the following facies distribution (in landward order):

1. **Shelly marine mud;** dominated by *in-situ* bivalves;
2. **Marine mud;** seismic data show this onlaps landward;
3. **Concretionary/erosive facies;** consisting of cobble-sized hardened mud clasts and abraded marine shells;
4. **Sandwave facies;** comprised of well-sorted quartzose sands, formed into numerous flood-orientated bedforms of up to 2 m in height and 30 m in wavelength.



Re-sampling of river sediments in the wet season showed little change in the facies pattern. The sandwave crests had been reworked to produce a seaward asymmetry but little seaward migration was evident. These observations indicate a net landward transport of bed sediment during the dry season and minimal seaward transport during the wet season of 1995/6. Dry-season conditions dominate for 8-10 months of most years, so long-term net sediment fluxes would probably be landwards. Bedload is therefore probably transported out of the river only during episodic large-scale flushing events.

NORTHEAST AUSTRALIAN CYCLONIC VARIABILITY DURING THE LATE HOLOCENE

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From November through to April the coast line of northeastern Australia is subject to the effects associated with the development and passage of tropical cyclones. High energy waves generated by intense storms are mostly destructive in nature, occasionally, however, specific sites become areas of sediment accretion due to factors such as bathymetry and orientation. In northeastern Australia the near-shore zone is often composed of biogenic carbonates such as corals or shellfish. This material maybe driven shoreward by uprushing waves and deposited into a storm ridge; continued deposition of material by successive cyclones will form a prograding sequence of ridges. Radiocarbon ages of coral and shell from individual units provide the age of organism death, reflecting in most instances cyclone occurrence. In essence, a sequence of storm ridges represents a chronologic record of the passage of intense tropical cyclones.

Both Curacoa Island in the Palm Island group and Princess Charlotte Bay have been sites of sediment accumulation for the past 6,500 and 2,500 yrs B.P. respectively. Both sites were surveyed, a series of pits were dug into the storm ridge sequences and stratigraphic boundaries noted. ^{14}C ages from individual depositional units provide a time series of storm events at each site. Samples with conflicting stratigraphy and radiocarbon ages were interpreted as reworked deposits and excluded from the time series.

The ^{14}C age series were analysed using Bayesian statistical methods, incorporated into a radiocarbon calibration and analysis program [OXCAL v3.0; Bronk Ramsey, 1994]. The results indicate long term local fluctuations in cyclonic activity at both sites. Correlation of the data from both sites provides support for regional fluctuations.

THE CHARACTER AND AGE STRUCTURE OF VALLEY FILLS IN UPPER WOLUMLA CREEK CATCHMENT, SOUTH COAST, N.S.W.

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This presentation characterises the nature of floodplain deposits at the base of the escarpment in part of the granitic Bega catchment, on the South Coast of N.S.W. Extensive valley fills, around 12 m deep but no greater than 300 m wide, have formed in upper Wolumla Creek, a north-south aligned catchment draining 90 km^2 in the south east of Bega catchment. These valley fills are a type of cut and fill floodplain, comprising series of alternating, horizontally bedded sand and mud units, reflecting reworking of deeply weathered granites of the Bega Batholith. Sand units are deposited on floodplain surfaces, as floodouts and sand sheets, or as bedload within channel fills. Mud units are generally organic rich (up to 29 % organics), and are deposited from suspension in swamps or on floodplain surfaces. A distinct downstream fining trend is evident in the composition of the floodplain.

Four radiocarbon age determinations suggest that virtually the entire valley fill was excavated prior to 6,000 years BP, leaving remnant terraces at valley margins. Re-incision into the valley fill is indicated at around 1,000 years BP, following which the channel refilled and the valley fill re-established. Portion plans dated from 1865 refer to the study area as 'Wolumla Big Flat', and show a large area of swampy terrain seemingly similar in character to an intact tea tree swamp in the upper part of an adjacent catchment today. Within a few decades of European settlement, the valley fill had been re-incised once more. Upper Wolumla Creek now has a channel over 10 m deep and 100 m wide in places, draining a catchment area less than 20 km^2. This scale of incision is at least a magnitude larger than any incisional phase that had occurred in the previous 6,000 years.

RIPARIAN VEGETATION AS A CONTROL ON HYDRAULIC GEOMETRY AND CHANNEL EVOLUTION IN A NATURAL RIVER SYSTEM - THURRA RIVER, EAST GIPPSLAND.

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NSW, AUSTRALIA 2109

The vast majority of alluvial rivers in Australia have been geomorphically altered by human activity. With some recent exceptions, geomorphic studies of Australian rivers have paid scant regard to the extent and nature of anthropogenic alteration to fundamental controls within the fluvial system. In many cases contemporary river behaviour is nothing like that in the 5000 - 6000 years (ie current climatic regime) preceding European settlement, yet extrapolations are often made over this time-frame based only on what is known from post settlement river behaviour.

A notion gaining increasing currency within river management circles is that there is consistency between present and past responses to catastrophic events. This perception takes no account of altered flood plain and channel boundary shear resistance, to say nothing of increased sediment load and a range of other altered parameters. Such oversimplifications are extremely dangerous if they become incorporated into management policy.

It is not possible to travel back in time and determine exactly how rivers behaved before European settlement, nor is it possible to ever return a degraded river to its pristine condition. However, much can be learnt about contemporary river behaviour by understanding as best we can what rivers used to be like and how much they have changed. This can be done in two ways: i) 'reconstruct' the pre existing catchment and riparian environment of a degraded river, hence determining how much the system has changed. ii) find an analogous "natural" system (ie an alluvial river having a fully vegetated catchment and a fully vegetated riparian zone) and measure contemporary hydraulic and alluvial behaviour. Comparisons can then be made with analogous degraded systems.

This paper presents preliminary results of an example of the latter scenario. The Thurra River in East Gippsland, Victoria, broadly satisfies the criteria of a natural and largely alluvial small river system (≈400km^2). It is not pristine, however, it remains completely forested, with a largely undisturbed riparian zone. The analysis utilised a GIS data base to account for disturbance within the catchment, including fire, logging and roading etc. as well as incorporating the natural catchment controls such as geology and vegetation communities and structure. A detailed assessment of hydraulic geometry is presented, which incorporates associated riparian vegetation composition and density, and LWD concentrations. Implications of this work to river management and palaeo-enviromental reconstruction are discussed

RIFFLE-POOL MORPHODYNAMICS - AN 1800 YEAR HISTORY OF CUT & FILL ALONG AN ARID UPLAND VALLEY

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Riffle-pool geomorphic assemblages provide useful insights into fluvial behaviour and history in non-alluvial settings. Detailed stratigraphic analysis and radiocarbon dating has yielded an 1800 year history of cut and fill episodes along Sandy Creek Gorge, which dissects a $60km^2$ catchment on the north-eastern flank of the Barrier Range in arid far Western NSW.

The well defined riffle-pool sequence is the product of structural control and fluvial hydraulics, and consequently dictates alluvial morphology and sediment storage along the valley floor. A string of ephemeral waterholes (pools) occupy valley constrictions (30-40m wide) corresponding to resistant bedrock outcrops and reflect concentration of scour due to flow convergence. Pools alternate with boulder bars (riffles) where valley expansions (80-100m wide) allow divergence of flow.

Along pool reaches, mostly fine-grained sediments lie inset within the coarse-grained flood plain and riffle elements. Excavations into the pool strata reveal a marked consistency of sedimentation: the modern channel carries coarse sandy gravels, but lies incised within a relict mud facies - now buried by actively aggrading (post-European) benches narrowing the channel. Pool reaches are preferentially scoured during floods sufficiently large to activate riffle-pool velocity reversal, while low flows prompt pool aggradation. Therefore the low-energy mud facies and their preservation are interpreted as indicating catchment stability and/or the absence of large floods.

Few studies have examined the issue of channel and flood plain sediment storage in arid-zone gorges, the implication being that such deposits have low preservation potential and therefore provide limited information. Geomorphic elements along Sandy Creek Gorge preserve a record of both extreme floods and intervening periods of relative quiescence over the late Holocene. Here, sediment storage and transfer is dominated by event-driven, disequilibrium behaviour. The marked morphologic and sedimentologic shift from mud-rich to sandy gravel channel-fills and inset benches are considered with regard to human impacts and the passage of major floods.

STRANDED TERRACES IN THE TVZ:
DEPOSITS OF A RAPIDLY ERODING MEANDERING RIVER

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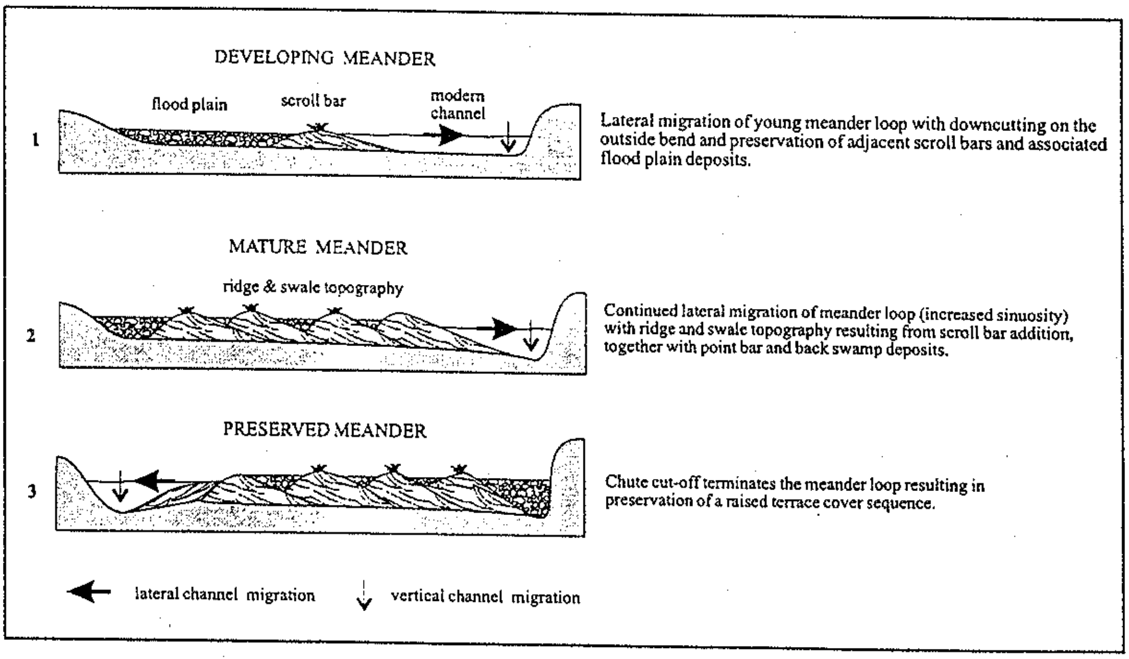
During the emplacement of the Taupo Tephra Formation by the Taupo eruption of 1850y BP (Froggatt & Lowe, 1990) the Kiangaroa Plateau in the Central North Island of New Zealand was reduced to a near featureless plain. Since this time, in the central part of the plateau, the Rangitaiki River has scoured a sinuous channel creating a spectacular flight of terraces in a strongly erosional regime (field 4; Woolfe and Balzary, 1996). Excellent exposure of these terraces, adjacent to the modern analogue, affords the opportunity to observe in detail the processes which have resulted in this morphology. Terrace treads are cut at the outside edge of meanders and subsequently partially filled by scroll and point bar deposits associated with the same loop (see figure). Rapid entrenchment rates (up to 5mm/y) allow the meander loops to be permanently abandoned following cut-off, and therefore preserved. Furthermore, we interpret the formation of these terraces to be part of a continual process of erosion and deposition, and not any episodic event, as has been suggested for terraces in many other river systems in New Zealand.



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COSMOGENIC ISOTOPES AS A GEOMORPHOLOGICAL TOOL - SOME LESSONS AND POTENTIAL FUTURE USES

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Determining the ages and erosion rates of landforms is important to studies of long-term geomorphic processes. These parameters of landscape evolution can be estimated from the abundance of cosmogenic isotopes produced by cosmic rays in samples collected from Earth's surface. Cosmogenic analysis has stimulated widespread interest among Quaternary geomorphologists and geologists because landscape stability and age are typically difficult to determine by other means.

This presentation is essentially designed to provide a brief overview of cosmogenic isotope analysis by outlining the theory and assumptions. Data from an ongoing project in East Antarctica, and the lessons learned from these are discussed. Finally, potential future applications of the method are outlined.

The aim of the Antarctic project is dating the retreat of the East Antarctic ice sheet since the last glacial maximum (LGM). The initial sampling and analysis of glacially polished bedrock in the Vestfold Hills, East Antarctica provided equivocal results. This is largely because of assumptions made about the erosivity of the ice sheet, and the use of striations as an indicator of negligible bedrock mass loss since glaciation. It appears that, at least in the Vestfold Hills, ice is ineffective in eroding bedrock, and striations, rather than being evidence for low rates of surface erosion, indicate recent exhumation from underneath tills.
A different sampling methodology was implemented as a result of these observations The latest cosmogenic analysis of sub-glacially derived erratics provide surface exposure ages of 12-9 ka. These ages correspond with ^{14}C-dated appearance of organic sediments in lakes sampled by other researchers and suggest an expanded ice sheet during the LGM.

In theory, cosmogenic analysis can provide chronological controls for a large variety of geomorphological and tectonic processes. Some of these, such as the uplift rate, timing, and relative vertical displacement of Earth's surface, have already been tested and will not be discussed here. The presentation will focus on the potential of cosmogenic analysis for constraining sediment accumulation rates and ages, such as those stored in alluvial terraces or caves, as well as whole basin erosion studies. If the method can be implemented to address these issues it may provide a minor revolution in the earth sciences.

PALEOMAGNETIC DATING OF WEATHERED REGOLITH AT NORTH PARKES MINE, NSW

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The ages of weathered, non-fossiliferous regolith materials are notoriously difficult to determine in Australia. Dating methods such as radiocarbon, luminescence and U-series are generally limited to the last few hundred thousand years, while techniques such as K/Ar and ESR are only applicable to certain mineral phases which may occur only rarely in regolith sequences. However, because of the common occurrence of secondary iron-rich minerals, the techniques of paleomagnetism have wide application in regolith studies. In this study we have used paleomagnetism in an attempt to establish a chronological framework for weathered regolith materials at North Parkes Mine, NSW.

At North Parkes Mine the orebody is a porphyry copper-gold deposit related to Late Ordovician quartz monzonite intrusions. The orebody is overlain by up to 30 m of strongly weathered regolith, excellent exposures of which occur in two open-cast pits (E22 and E27). In both pits, transported sediments unconformably overlie *in situ* weathered bedrock saprolite. The transported sediments infill broad depressions (up to 400 m wide and 25 m deep) which have little or no expression in the modern landscape. They are mottled clay-rich materials composed dominantly of kaolinite, with secondary dolomite, silica and hematite. The high degree of weathering of the transported sediments makes interpretation of their depositional environment extremely difficult, but we tentatively refer to them as valley fill sediments, probably partly colluvial and partly alluvial.

From three to six oriented paleomagnetic samples were collected in 6 cm^3 plastic boxes from each of 9 sites: four sites in saprolite, and five sites in the valley fill sediments. Both thermal and alternating field (a.f.) demagnetisations were carried out on the samples to isolate the Characteristic Remanent Magnetisation (ChRM). Natural Remanent Magnetisation (NRM) directions (i.e. prior to demagnetisation) were scattered, with a general tendency to cluster around the present field direction at the site, consistent with on-going, contemporary weathering. However, with progressive demagnetisation many of the samples revealed a reverse polarity component, indicating aquisition during weathering prior to the Brunhes/Matuyama polarity transition (0.78 Ma). Three samples from the base of the valley fill in pit E27 yielded a mean pole position of 135.5°E, 72.7°S, which indicates a possible age for weathering in the range 20-40 Ma depending on which Apparent Polar Wander Path (APWP) for Australia is used (c.f. Idnurm 1985; Musgrave 1989).

From our preliminary paleomagnetic results we infer that weathering of regolith at North Parkes Mine has been an on-going process since at least mid-Tertiary time.

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REGIONAL CONTRASTS IN WEATHERING, GLACIAL SEDIMENTS AND TERRAIN SUGGESTS LONG TERM SUBAERIAL EXPOSURE OF THE VESTFOLD HILLS, EAST ANTARCTICA

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The Vestfold Hills exhibits marked contrasts in the weathering surface, glacial sediments and terrain between its eastern and western parts. The boundary between these zones coincides with a regional chemical boundary termed the 'salt line'. The area west of the salt line is saturated with marine-derived halite and thenardite that are particularly aggressive agents of rock weathering. In contrast, the area east of the salt line exhibits significantly fewer deposits of these salts.

Rock surfaces west of the salt line are characterised by well developed weathering forms, while glacial polish and striae are largely absent. In contrast, rock surfaces to the east commonly retain glacial polish and striae. In places, differential weathering has caused thin basaltic dykes and felsic veins to stand above the surrounding gneiss. The rate of lowering of the gneiss and dykes to the west of the salt line has been estimated at 0.024 mm and 0.015 mm per year respectively (Spate et al. 1995). These measurements suggest that the weathering surface in parts of Vestfold Hills may record more than 70 ka of subaerial exposure.

Glacial sediments are much more abundant, coarser and better sorted northwest of the salt line than to the southeast. The abundant grus produced by physical weathering is coarser grained and better sorted than that produced by subglacial erosion. Such sediment lying on the land surface would be transported and redeposited during glacial advances. The change in nature of the sediments to either side of the salt line, together with the weathering forms found on clasts in the moraines, indicates that the weathering surface prior to the last glacial advance was similar to that of today and must also have developed during long periods of subaerial exposure.

The terrain to the west of the salt line has modal hilltop heights of 41-60 m and that to the east 101-120 m. The minimum period of subaerial exposure inferred to create this 60 m contrast in maximum height of the gneiss terrain is 2.5 Ma. Although the number of glaciations is unknown, it is clear that the contrast in terrain and sediments of the Vestfold Hills has been created by cumulative subaerial exposure and glacial removal of weathered sediment for very long periods extending back into the Tertiary. The antiquity of the Vestfold Hills weathering surface and terrain has not hitherto been fully appreciated, nor has the length of time that this oasis may have been free from the East Antarctic ice sheet.

Keywords: Quaternary, salt, weathering, sediment

DATING GLACIAL EVENTS ON THE CENTRAL PLATEAU, TASMANIA

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On evidence from outlet valleys the Tasmanian Central Plateau has been glaciated on at least four occasions. The Last Glaciation (LG) was the least extensive and ended more than 10,000 years BP. Limits of the LG have been traced across the Plateau from discontinuous end moraines. Outside the LG moraine complexes there are lower moraines with eroded crests and exfoliated surface boulders of the Penultimate Glaciation (PG). Older glacial events have not yet been definitively identified on the Plateau but the evidence in the outlet valleys of the Mersey, Forth and Meander rivers and on the plains below the northern escarpment of the Plateau is indicative older glaciations.

Dating the glacial events has been attempted by a number of techniques including relative dating techniques, ^{14}C dating, and cosmogenic isotopes.

1. Relative dating techniques

The main techniques used are the geographical position of more extensive older glaciations found beyond the limits of recent glaciations, the erosion and weathering of the moraines and the weathering rinds developed on dolerite clasts.

2. Radiocarbon dating

As a result of ice scouring on the dolerite surfaces and the deposition of moraines the Plateau area contains many lakes and bogs. Coring of mainly intermorainal bogs has allowed dating of algal mud, an indication of warming during LG deglaciation. Other ^{14}C dates have been employed in the vicinity of the Plateau with mixed results.

3. Cosmogenic dating ^{36}Cl, ^{26}Al and ^{10}Be.

On the Plateau there are large exposures of ice-abraded dolerite that have remained essentially unaltered since deglaciation of the LG. Surfaces that relate to the PG or older events are also in evidence. There is also an abundance of large dolerite boulders deposited by glacial action. In other places the AMS technique has been successfully applied to the measurement of in situ ^{36}Cl to obtain exposure ages, erosion rates and time of glacial abrasion. Samples have been gathered from dolerite boulders within the LG limits and immediately outside. These are currently awaiting measurement at ANSTO.

Extension of the cosmogenic program is underway in 1996 where ^{10}Be and ^{26}Al will be measured in quartzite in the adjacent valleys of the Mersey and Forth and in the Cradle Mountain area.

CHANGES IN TERRAIN RESISTANCE TO LANDSLIDING, FOLLOWING EROSION EVENTS: CONCEPTS AND METHODOLOGY.

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The susceptibility of terrain to landsliding depends on the frequency/magnitude characteristics of the impinging triggering agents and the inherent sensitivity of the terrain (terrain resistance). Terrain resistance, in turn, is determined by excess strength (shear strength minus shear stress) and the way in which surrounding slopes amplify or diffuse the influence of the triggering agent (ambient filtering).

Input/response modelling in landslide-prone hill country of New Zealand commonly reveals unsteady systems behaviour. For example, previous attempts to establish the threshold level of rainfall required to trigger landslides (or a given degree of landsliding) have met with only partial success, because of what appears to be the temporal variability in terrain resistance. While some changes in terrain resistance can be attributed to variation in antecedent hydrological conditions within the slope, or to changes in land use, other, less well-understood changes in resistance, can be related to the development of particular geomorphic conditions inherited from previous erosion events.

Observations of the effect of sequential landslide events in New Zealand point to four mechanisms which may be used to explain the variation in catchment resistance inherited from prior events. These mechanisms may be characterised in the following way:

1. change in sediment mobility and availability
2. regolith stripping: reduction of regolith availability (exhaustion model)
3. depositional loading
4. depositional hardening

An investigative framework to test the validity of these mechanisms is proposed. This involves several stages: identifying the factors responsible for controlling terrain resistance, determining how they change with event processes, establishing the extent and distribution of these changes within the catchment, and determining their significance for stability.

OCCURRENCE OF RAINFALL-TRIGGERED LANDSLIDES IN RELATION TO RAINSTORMS IN NEW ZEALAND

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Rainfall-triggered landslide events are a common problem in New Zealand and some have caused extensive damage. Their occurrence throughout the country has been investigated by way of regional or site studies by various institutions, such as: universities, territorial and regional authorities, Crown Research Institutes, private consultancies, and transport authorities. Of course, the output from these investigations is strongly dependent on their specific aims. These studies use different methodologies and techniques related to the nature of the individual problem being investigated, which makes comparison difficult. However, these investigations demonstrate the widespread influence of landslides on all aspects of life and environment and illustrate the need for further detailed investigation.

On the regional scale, studies relating landslide occurrence to rainfall distribution in space and time are rare, which is surprising because of the high yearly total damage caused by rainfall-triggered landslides in New Zealand. The rainfall/landslide relationship has potential value to farmers, land managers, politicians, engineers, territorial and regional officials, transport authorities, and insurance companies. Historical records indicate that most parts of the country can expect to suffer damage from this phenomenon. Other overseas agencies have already responded to this need. For example, the U.S. Geological Survey established a real time landslide warning system during heavy rainfalls in the San Francisco Bay region, California.

For this investigation, three different regions within the North Island of New Zealand have been chosen to compare regional behaviours and characteristics resulting from the rainfall/landslide relationship. The regions are Northern Hawke's Bay, Wairarapa, and Wellington. They were selected because of the availability of the necessary temporal and spatial rainfall data, a good landslide record, physical environment differences and a complete aerial photo coverage for these areas, especially after highly damaging landslide events.

This study aims are:

1. establishing regional thresholds for the rainfall trigger, by comparing historical records of landslide occurrence with time series rainfall data,
2. relating these thresholds to antecedent soil water conditions,
3. analysing for one episode per region the extent of landslide occurrence and the relationship to rainfall distribution,
4. summarizing and characterising the similarities or differences between these regions.

The overall intention is to establish regional thresholds and to develop some ideas of how rainfall cells trigger landslides and which factors prepare and control the pattern and nature of occurrence.

RELATIONSHIP BETWEEN LANDSLIDE FREQUENCY AND STORM RAINFALL IN WAIPAOA CATCHMENT, EAST COAST, NEW ZEALAND

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The relationship between landsliding rate and storm size was identified as part of a sediment budget for the Waipaoa catchment, on the east coast of the North Island, New Zealand. The 2204 km^2 catchment is situated in a tectonically active zone experiencing uplift of the order of 3 mm/yr. The catchment is underlain mainly by Tertiary (mudstones and sandstones) and Cretaceous (argillites and greywackes) rocks, and comprises 16 land types, four of which are susceptible to landslide erosion. The four land types comprise 45% of the catchment, and one, which comprises 23% of the catchment and is a major sediment contributor, is the main focus of this study.

Representative 5-10 km^2 sub-catchments within the land types were chosen for analysis. Landslide frequencies were calculated for a variety of storm sizes for which air-photo records existed. Storm rainfalls ranged from 100-600 mm. Field observations and measurements were made to establish average scar volumes and debris tail thickness in order to calculate sediment generation and delivery volumes. The resulting landslide frequency-storm rainfall relationship was then applied to the total storm history derived from rainfall records. By summing inputs for individual storms over the length of the rainfall record, the total sediment generated from the landslide susceptible terrain was calculated throughout the Waipaoa catchment since European pastoral farming/deforestation. Landslide frequencies for the same storm set in areas under indigenous vegetation were also calculated and are at least an order of magnitude lower than those for pasture. This is in agreement with the results of a number of other short and long-term studies in similar terrain.

The budget for the last 50 years (approx.) was based on records from local rain gauges near to the sub-catchments analysed. However in order to extend the budget back to European arrival a rainfall record from Gisborne Harbour begun in 1890 was used and storm rainfalls for the inland sites estimated by regression analysis based on the relationship between recent storm rainfalls at Gisborne Harbour and inland sites and mean annual rainfalls.

The results will be used to identify the contribution of landsliding to the total catchment sediment budget, and to help predict the effects of two likely future trends, afforestation and a climate change related increase in storminess, on sediment input in the Waipaoa catchment.

Comparison of results with those for similar landslides in the Tutira catchment (Northern Hawke's Bay, NZ) and the Berkeley Hills (California, USA) indicates that the relationship between landslide frequencies and storm size are of similar form at each site, suggesting that the method may be useful at other sites with similar basin geomorphology.

EVENT-INDUCED CHANGES IN LANDSURFACE CONDITION - IMPLICATIONS FOR CATCHMENT STABILITY

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This paper describes a change in overall catchment susceptibility to landsliding - specifically as a result of a large cyclonic rainstorm event. Change in susceptibility is reflected by change in the contemporary landsurface condition of a given area, as it is modified by a geomorphically effective agent such as a large rainfall event.

Landslide episodes in the New Zealand hill country involve processes of displacement, evacuation, transport and redeposition of material throughout a catchment. Crozier (in press) considers that the response to these processes includes mechanisms described as regolith stripping, depositional loading and depositional hardening. These mechanisms have geomechanical implications and are thought to influence terrain resistance and subsequent erosional behaviour, thus affecting the inherent susceptibility of the catchment to future landsliding.

The response to these processes should be detectable as a change in landsurface condition. The contemporary landsurface condition of a unit area is both a product of the erosional processes that have already occurred, and a control on the susceptibility of that area to subsequent erosion. This is because the contemporary landsurface condition is an expression of the various slope and material parameters that determine strength and stress relationships, and hence susceptibility to landsliding. The change in landsurface condition of a given area, resulting from a large event such as a cyclonic rainstorm, will be paralleled by a change in stress/strength parameters, and hence in the inherent stability of that area. Five classes of Contemporary Landsurface Condition are recognised: "Undisturbed", "New Scars" and their associated "Recent Debris", "Old Scars" and "Colluvial Surfaces".

In March 1988, Cyclone Bola devastated New Zealand's North Island east coast hill country, causing extensive landsliding. Using aerial photography, the distribution of Contemporary Landsurface Condition classes within the catchment of Lake Waikopiro in northern Hawke's Bay has been mapped both before and after this event. Comparison of these maps shows the extent of change in distribution of Contemporary Landsurface Condition classes. The nature of these changes can be analysed within a Geographical Information System, permitting an identification of the implications of these changes. Any change in the pattern of Contemporary Landsurface Condition distribution reflects migration of areas of susceptibility over time, suggesting that the mechanisms described by Crozier (in press) are operating. On the assumption that landsurface is in fact a reflection of material properties controlling stability, change in distribution of Contemporary Landsurface Condition classes shows at least a change in the likely location and distribution of future landsliding. Further, change in relative frequencies of Contemporary Landsurface Condition classes indicates that susceptibility to landsliding for the catchment as a whole is changing.

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MODELLING TROPICAL HUMID KARST LANDFORMS

Frank AHNERT (Aachen) and Paul WILLIAMS (Auckland)

An existing landform development program SLOP3D has been modified to simulate the 3-D development of karst landforms such as dolines/cockpits,polygonal karst and towers. Two questions are considered:

1) what are the minimum requirements for the development of particular karst landform types in terms of topographical conditions, material conditions and process conditions ?

2) are different form types the result of different environments or can they develop as successive stages under unchanging environmental conditions ?

The model surface is defined by a square grid of points, each with 8 neighbours. From each there are 8 potential directions along which runoff may flow, although it follows the steepest gradient. No distinction is made between runoff styles, whether surface or subsurface (epikarst). The amount of rock removed (R) in solution at a surface point per model unit time is expressed by

$$R = K1.\ Q^{m}.S^{n}$$

where K1 is a solubility coefficient, Q is local runoff, S is slope gradient and m,n are exponents, the values used here being m=0.33 and n=0.1.

In the model runs rainfall is spatially and temporally uniform. Runoff infiltrates into the rock below at the lowest points of enclosed depressions. At a pre-set depth lies an ultimate baselevel of denudation. When a surface point is lowered close to this, the local slope is steepened by basal sapping.

Four models, some with two cases, were run to explore the influence of (1) topography, (2) structure, (3) topography and flow divergence, and (4) structural control and flow divergence.

Models 1 and 2 show that locally higher solution rates caused by flow convergence lead to the development of dolines, but neither of the models result in polygonal karst or tower karst. Sapping at the karst water-table does not by itself cause towers or cones to develop. Models 3 and 4 show that for cones and towers to develop there is an additional minimum requirement that the solution rate is markedly lower at points of flow divergence (such as summits) than at points of convergence (such as doline bottoms). This also accounts for the sharpening of ridge crests and their junctions in the case of polygonal karst.

In conclusion, there is no need to invoke any climate factors, except for the sufficient availability of water, to produce polygonal karst. The frequent occurrence of tower and cone karst in the humid tropics may simply be due to the long continuity of uninterrupted karst development. Thus tower and cone forms may be the normal late stage of development, that may have been interrupted in mid-latitudes by particular climatic histories, sometimes involving glaciation and periglaciation.

KARST OF THE CAINOZOIC LIMESTONES OF THE OTWAY BASIN

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This paper will discuss the diverse karst features of the Cainozoic limestones of the Otway Basin in the context of lithological variation and processes of speleogenesis.

The Tertiary and Quaternary limestones of the Otway Basin include Miocene and Oligocene marine limestones and Pleistocene calcareous dune and beach facies. Karst development in such limestones of high primary porosity and high permeability presents particular problems in terms of the usual concepts of speleogenesis. Karst development in these different limestone lithologies also shows substantial variation across the basin and between the different lithologies. Although environmental factors such as relief and climate do not vary greatly across the basin, there are significant changes in lithology, structure and underground water conditions.

The karst shows important differences in the number and type of cave present per volume of limestone, total passage length, passage orientation, passage size, and cave form. Substantial differences in other karst features are also evident such as the presence of the distinctive cenotes and other surficial features in some area and yet complete absence in other areas which appear similar. The different karst features can be explained primarily by lithological variation.

TUESDAY 1ST OCTOBER

AN INVESTIGATION OF THE GEOLOGICAL TRACE OF THE TSUNAMI GENERATED BY THE 1755 "LISBON" EARTHQUAKE.

ROBERT HINDSON (DIVISION OF GEOGRAPHY, COVENTRY UNIVERSITY, PRIORY ST., COVENTRY CV1 5FB., UNITED KINGDOM.)

A description is given of a distinctive marine deposit at Boca do Rio on the Algarve coast of Portugal. It is proposed here that the sediment accumulation was deposited by the tsunami generated by the Lisbon earthquake of November 1st, 1755 AD. Historical documents describe the eyewitness accounts of the occupants of a nearby fort who observed the tsunami surging into the Boca do Rio which was an estuary at this time. The deposit is found within a sequence of estuarine and fluvial muds, and can be clearly distinguished from these sediments on the basis of sedimentology, detailed textural characteristics and micropalaeontology (Foraminifera and Ostracoda). The sedimentological and textural evidence suggest that the deposit was laid down under high energy, turbulent hydrodynamic conditions which lead to the deposition of a wide variety of particle sizes from gravels to clays. The analysis also provided evidence for the provenance of the deposit. The gravels show strong signs of biogenic erosion and are interpreted as having been derived from the offshore zone. The sands contain open marine Foraminifera and Ostracoda and are thought to have been derived from the offshore zone and local dunes. The mud constituent is rich in Foraminifera and Ostracoda which are characteristic of the intertidal zone (saltmarsh/mudflat) and are thought to have been eroded from the estuarine surface onto which the tsunami surged. Thermoluminescence dates for the sand within the deposit give an age of 260±60 years BP, thus providing further strong evidence for the tsunamigenic origin of the deposit.

THE MAGNITUDE AND FREQUENCY OF TSUNAMI: SOUTH COAST OF NEW SOUTH WALES

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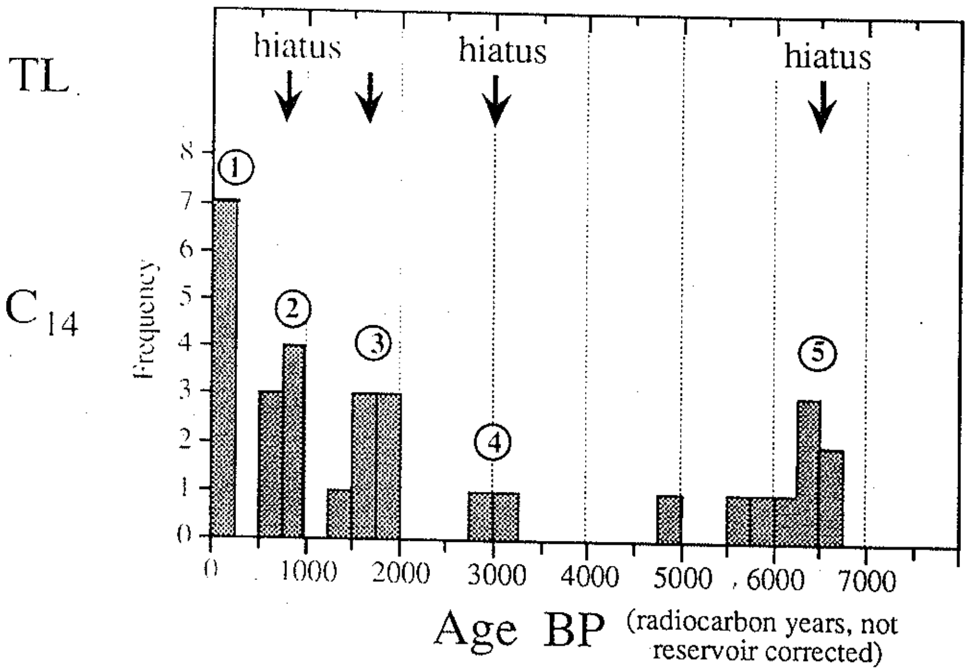
Tsunami waves produce 4 general categories of depositional and erosional evidence that can be preserved in the geological record. Individual items within these categories are signatures that, singly or in combination with each other, uniquely define the impact of tsunami in the coastal landscape. The array of signatures provide directional information about the origin of tsunami in the west Tasman Sea and, when combined with radiocarbon and thermoluminescence dating, indicate that 6 events of varying magnitude have affected the New South Wales coast during the Late Holocene (see Figure). The source of these tsunami appears to be large submarine slides on the continental slope. The first event probably occurred concomitantly with the approach of sea-level near modern levels around 8000 BP. The latest event occurred around 800 years BP although there is sufficient evidence to suggest that one event may have occurred just before European settlement. The recurrence interval of tsunami is now approaching one event every 600 years.



The impact of these tsunami upon the coastal landscape has been profound. Several signatures provide estimates of the magnitude of run-up of these events. The height to which chaotic mixes of sediment and imbricated boulder stacks have been deposited and the height of headlands that have had a smear of clay, sand and shell plastered across them give general estimates of the run-up height. The elevation of eroded landscape features on headlands gives information about the depth and velocity of flow. The presence of sand laminae and splayed sand units within deltaic sediments permit the landward limit of tsunami impact to be determined. This geomorphic evidence indicates that the largest tsunami waves swept sediment across the continental shelf and obtained flow depths of 15-20 m at the coastline with velocities in excess of 10 meters per second. Along cliffs, and especially at Jervis Bay, waves reached elevations of 40-100 m with evidence of flow depths in excess of 15 m. Preliminary evidence on the Shoalhaven delta indicates that waves penetrated 10 km inland for at least one event. This geomorphic evidence suggests that the New South Wales south coast is subject to tsunami waves an order of magnitude greater than that indicated by historic tide gauge records.

HIGH ENERGY WAVE DEPOSITS INSIDE THE GREAT BARRIER REEF: DETERMINING THE CAUSE - TROPICAL CYCLONE OR TSUNAMI

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A hydrodynamic approach is used to determine whether tsunami or tropical cyclone generated waves were responsible for the deposition of fields of well imbricated very large rock boulders (up to 287 tonnes) along the coast of Cairns inside the Great Barrier Reef. Calculations of the overturning moments show that only tsunami are capable of moving such large boulders in this environment. It is hypothesised that large tsunami (>11 m) have been able to penetrate the Great Barrier Reef through wide (5 - 10 km), 50 - 70 m deep passages between individual reefs. Three such passages each approximately 35 km apart and oriented in the same direction exist in the Cairns region. It is likely that these passages have funnelled and amplified the tsunami. The preferential location of eroded coral boulders up to 3 m in length on reef flats alongside these passages and their absence on other reefs throughout the region provide further evidence that extremely high energy waves have been able to penetrate the Great Barrier Reef into the inner channel adjacent to the mainland. The Carbon - 14 ages of the coral boulders on these reef flats matches closely the ages of coral fragments pinned below the very large rock boulders along the coast. These ages suggest that two separate tsunami events occurred in the Cairns region over the last millenium.

Shaken and Stirred: The Effects of Marine Transgression, European Colonisation, and Earthquakes on Coastal Sedimentation

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Abstract:

^{14}C and ^{137}Cs chronologies of sediment accumulation were obtained from cores taken from Wellington Harbour, New Zealand. A 10000 year chronology records the Holocene transgression, European colonisation, and variations in the general sediment accumulation rate caused by earthquake uplift and anthropogenic activity.

In general, rates increased at the beginning of the Holocene marine transgression, but by about 5000 years BP they stabilised. Harbour-wide, these rates remained stable until the second half of the 19th century when deforestation by European settlers caused order of magnitude increases in sediment accumulation. In the past 40-80 years, rates have increased again as a result of urban growth and river channel management, although the effects are less pervasive. Harbour-wide influences can be placed in two categories, natural and anthropogenic, the latter being recent contributions to a sedimentary regime dominated by the Holocene marine transgression. Overall, rates vary between a high of about 60 mma^{-1} to a low of 0.1 mma^{-1}.

Sediment accumulation rates indicate that two major earthquake uplift events had only a local effect on harbour sediments. Anthropogenic influences are considered to be more significant sedimentologically than earthquake activity.

THE DEVELOPMENT OF NEW ZEALAND'S LARGEST BARRIER ISLAND: MATAKANA ISLAND, BAY OF PLENTY

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Matakana Island, which encloses Tauranga Harbour, formed during late Quaternary time. The older part of the island comprises tephra-covered Pleistocene terraces. The lowest Pleistocene terrace, of probable Last Interglacial age, developed as a relict foredune plain. Although the plain has since been tectonically downwarped to a level at or below present sea level, deposition upon its surface of c.13m of tephra has enabled elements of the original ridge/swale topography to be preserved several metres above sea level as subdued shore-parallel ridges.

The larger, seaward, part of the island consists of a prograded Holocene sand barrier, which is 24 km in length. Geomorphological, sedimentological, mineralogical and shallow stratigraphic investigations, together with tephrochronology and radiocarbon dating, have enabled the evolutionary history of the barrier to be reconstructed. The barrier originated between 5500 and 6500 years BP and initially formed in two sections separated by an additional entrance to Tauranga Harbour which was sealed off c. 3500 years BP. The barrier prograded seawards to form a relict foredune plain. Average progradation rates declined from >0.4 m/y before 3500 years BP to <0.2 m/y since. Parabolic dune activity affected various parts of the barrier throughout its history. The largest transgressive dunes developed prior to human settlement but there has been significant dune formation since Maori settlement which commenced c. 600 years BP.

Both ends of the barrier, adjacent to the present two harbour entrances, are highly dynamic. The southeastern end, adjacent to the Mount Maunganui entrance, extended markedly during the past 600 years, reducing the width of the entrance channel from 3.2 km to 0.5 km. During the same period the northern entrance narrowed from c. 2.2 km to 0.4 km. It is likely that barrier evolution has been affected by changing entrance dynamics resulting from changes to the tidal prism induced by sedimentation within the harbour. The detailed progradational history of the cental part of the barrier may have been affected by changing coastal sediment budgets resulting from the growth and decay of ebb-tidal deltas adjacent to present and former harbour entrances.

PRELIMINARY RESULTS OF A LATE QUATERNARY DRILLING PROJECT, CANTERBURY, NEW ZEALAND.

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A pilot drilling project in Gebbies Valley, Banks Peninsula, Canterbury, has recovered 75 m of Late Quaternary material. The sediments are dominantly lacustrine and lagoonal in origin but contain several loessic soils and some fluvial gravels near the base. Based on Carbon-14, thermoluminescense dating and pollen analyses, it is tentatively concluded that the site contains a substantively complete record of the last glacial-interglacial cycle and may extend considerably further back in time. A notable feature of the site is the thick deposits provisionally associated with isotope stages 5a-d. Except at the base, the sediments preserved are exclusively either organic or greywacke derived coarse silts. This is inconsistent with a primary source from either the Canterbury Plains, where greywacke gravels dominate, or from the local area which is mainly basaltic with some rhyolites. It is concluded that most of the core record comprises primary and secondary reworked loess. Preliminary sedimentary analyses suggest that there may be a relationship between the particle size distribution of this loess and the paleowind velocities.

Banks Peninsula is tectonically stable in the Late Quaternary and there are a number of good sea-level indicators in the core. This site will produce a key relative sea-level curve for this part of the South West Pacific. A summary of the most up to date results will be presented.

BED-LEVEL CHANGES IN TE WERAROA STREAM, EAST CAPE, NEW ZEALAND.

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Te Weraroa Stream is a tributary of the Waipaoa River, which drains into Poverty Bay on the East Coast of the North Island, New Zealand. The18.5 km^2 headwater catchment is underlain by shattered bedrock and experiences a high annual precipitation. Erosion rates in the catchment were accelerated significantly at the turn of the century by the complete removal of the native forest cover. The channel system aggraded rapidly in response to the influx of sediment supplied by mass movements and gullies. The most prominent erosional feature is the 0.4km^2 amphitheatre gully known as the Tarndale Slip. Reforestation began in 1960, and presently the first cycle harvesting is underway.

Bed level changes in Te Weraroa Stream have been monitored from 1948 at 13 cross-sections along the 10.5 km long channel. The cross-sections start 1.6 km from the confluence with the Waipaoa River and extend for a distance of 7.2 km upstream. They are spaced at 1610 m (one-mile) or 400 m (quarter-mile) intervals and were surveyed annually up to 1968 and biannually up to 1980. Since 1980 only five of the 13 locations have been surveyed regularly. Aerial photographs are available for the period since 1939. The cross-section surveys and aerial photographs provide a record of the changes that have occurred to the channel of Te Weraroa Stream in the last 57 years.

If the water and sediment discharges in natural rivers are in equilibrium no scour or deposition occurs but, in the absence of a compensatory increase in discharge, an increase in the sediment supply will cause the channel to aggrade. Aggradation in Te Weraroa Stream was initiated by an influx of bed material load that was too great in volume (and to a lesser extent, too coarse) to be transported by the preexisting gradient. Active channel width has increased and the rise in bed level rise ranges from seven metres to over twenty metres. The rate of bed level aggradation has decreased in the period since 1960.

In this paper we examine local, episodic aggradational trends in selected reaches of Te Weraroa Stream downstream from the Tarndale and relate these changes to variations in the amount of sediment supplied to the channel from point sources on the surrounding hillslopes. We also examine the behaviour of longitudinal bed profiles reconstructed from the cross-section survey data in relation to the form of a similarity profile, in an attempt to model the channel's response to sediment overloading.

BED MATERIAL CHARACTERISTICS OF THE WAIPAOA RIVER, EAST CAPE REGION, NEW ZEALAND

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The 102 km long Waipaoa River drains into Poverty Bay. Most (97.5%) of the indigenous forest in the 2150 km^2 catchment was cleared in the period 1820-1920. In the headwaters conversion to pasture, which was accomplished in the period 1880-1920, initiated a phase of intense erosion in the hill country where many of the underlying rocks are poorly indurated sandstones, siltstones and mudstones of Cretaceous to Tertiary age. The channel system aggraded in response to the influx of bed material load supplied by mass movements and gullies. Suspended sediment yields in headwater subcatchments also are high (7000 - 17 000 $t/km^2/y$), and the suspended sediment load predominately is in the silt-clay size range. The most prominent erosional features in the catchment are large amphitheater gullies, such as the Tarndale Slip.

In its lower reaches (0 - 45 km) the river exhibits a single thread, meandering channel, with a gravel-sand bed and cohesive banks. The river is entrenched between terraces and low hills from 45 to 77 km. A narrow gorge is present between 77 and 92 km. Upriver from the gorge the channel is braided. For the period 1948-1988, the amount of aggradation in the upper reaches was >5 m. In the lower reaches it was ~0.5 m.

As part of an investigation of the fluvial transfer of the coarse bed material load through the catchment we conducted a bed material survey of the entire Waipaoa river, from the headwaters to the mouth. Samples were collected at 1 km intervals along the entire length of the mainstem, and at locations immediately upstream from the confluence along all the major tributaries. The samples were collected from as near to the channel centre-line as practicably possible. Bulk (50 kg) subsurface samples were collected between 0 and 94 km. Areal samples were collected, using the Wolman method, at sampling locations between 94 km and 104 km where the presence of large particles made it impractical to undertake sieve analyses. In every 5th sample the lithology and shape of all particles >16 mm in diameter also was recorded. Less comprehensive bed material surveys also were undertaken at 1.61 km (1 mile) intervals in 1950, 1956 and 1960. The long profile has been reconstructed from annual cross-section surveys undertaken at 1.61 km intervals throughout the period 1948-1960, and in 1996.

The bed material in the upper reaches is bimodal. The sand - gravel transition in the Waipaoa River occurs between 12 and 13 km upriver from the mouth. Over the remaining 90 km the bed material D_{50} declines from 5 to 2 mm, but the rate of decrease is higher for the higher percentiles and over the same distance the D_{90} declines from 48 to 7 mm. The percent sand also increases in a downstream direction (from 33% in the headwaters to 46% in the reach upriver from the sand-gravel transition. The observed change in D_{50} is consistent for the period 1950-1995. The low rate of downstream fining likely is due to the conversion of the channel to a relatively fine, live bed condition in response to the influx of sediment that was a product of the late C19 to early C20 phase of forest removal in the headwaters.

RIDGE-FORMING ANABRACHING RIVERS: EXAMPLES FROM THE KIMBERLEY, WESTERN AUSTRALIA

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Alluvial reaches of rivers on the Kimberley Plateau of W.A. commonly form an unusual type of anabranching pattern. In these channels, within-channel sandy ridges separate the flow into individual subchannels. Such anabranching reaches are frequently confined by bedrock, both laterally and longitudinally, with only a thin veneer of alluvium separating the active channel from bedrock with occasional outcrops of bedrock visible within the subchannels. The ridges are mostly depositional features formed by sandy accretion in a largely vertical and downstream direction, and are always covered with trees and shrubs. Vegetation is crucial for providing stability to the unconsolidated sandy ridges and for promoting further sedimentation. Other requirements for the formation of these streamlined semi-permant islands appear to be a seasonal or highly variable flow regime, sandy bedload, and low stream gradients. Secondary currents which cause a spanwise undulation of primary velocity and bed shear stress may also play an important roll for the formation and preservation of these features. The hypothesis that this channel pattern forms an effective way to maintain bedload transport through low gradient channel reaches is supported from field examples.

ANABRANCHING CHANNEL SYSTEMS OF ARID CENTRAL AUSTRALIA: THE ROLE OF TRIBUTARY INPUTS

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River channels on the Northern Plains of arid central Australia range from single-thread to multiple-thread due to contrasts in the calibre of bed material which result from different catchment lithologies and patterns of tributary drainage. For the Sandover and Plenty Rivers, which transport bedloads of medium to coarse sands, channels are typically single-thread and relatively wide and shallow. For the Bundey, Woodforde and Marshall Rivers, which transport bedloads of coarse sands and granule gravels, many reaches are characterised by multiple subchannels occurring within a broader channel train. Subchannels are relatively deep and narrow and are separated by in-channel ridges - narrow, flow-aligned, vegetated features - or by larger islands. Ridges and islands can be considered either as depositional features (formed *in situ* by accretionary processes) or as erosional features (formed by excision from once continuous areas of floodplain). Vegetation plays a key role in the initiation, survival and growth of the depositional forms through its influence on flow and sediment transport. The resulting multiple-thread channel patterns are best described as anabranching.

Anabranching can be related to the influence of tributaries, for both the Bundey and Marshall Rivers alternate from single-thread to multiple-thread along their length in response to tributary inputs of water and sediment. Tributaries vary in character from those transporting bedloads of coarse sands and gravels to those carrying mainly suspended loads and their influence on the trunk channels can be two-fold: firstly, by the input of water and sediment to the trunk channels either prior to or in the absence of flows originating further upstream; and secondly, by the input of water and sediment to the trunk channels during flood flows. In both instances, ridges and islands can form as a result of various depositional and erosional processes including accretion in the lee of in-channel vegetation, by linear dissection of floodplains and by the formation and maintenance of deferred tributary junctions.

The influence of tributary inputs on the morphology of the trunk channels in central Australia is greater than that previously described for ephemeral drainage systems. By storing large volumes of sands and gravels and by influencing patterns of bed shear stress, the ridges and islands forming downstream of tributary junctions have a number of implications for the rates of bedload sediment transport across the low gradient plains of central Australia.

DOWNSTREAM DECREASING CHANNEL CAPACITY STREAMS IN AUSTRALIA: INCREASING OUR AWARENESS AND UNDERSTANDING OF THIS PHENOMENON

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Most streams increase or maintain their channel dimensions downstream as a consequence of increasing discharge as catchment area increases. The dimensions of a significant proportion of streams in south-eastern Australia, however, have a downstream decrease in channel capacity without any apparent loss of discharge to evaporation or groundwater infiltration. An increase in downstream flood frequency is associated with this decrease in channel capacity.

Investigation has shown that the decrease in channel capacity in many of the streams is a consequence of human impact, resulting from activities such as channelisation, or artificially increased sediment loads from mining or agriculture. However, in a number of streams it is a natural phenomenon; as a consequence, for example, of an avulsion or levee bank development. Interestingly, there is a small group of streams where the cause of the downstream decrease in channel dimensions has not been identified. It is hypothesised that the underlying valley geomorphology is influencing the present day morphology of these streams. To determine the validity of this hypothesis, the Tarwin River in Gippsland, Victoria was investigated. This investigation included consideration of planform characteristics, the influence of tributaries, hydraulic geometry and stream power relationships, of the channel and associated floodplain, on the development of channel capacity.

Given that these streams behave differently from the majority of fluvial systems, an understanding of the geomorphological relationships between the channel and the floodplain, and between the channel and its discharge, is vital in determining how to manage these systems.

QUATERNARY FLUVIATILE, LACUSTRINE AND AEOLIAN SEDIMENTATION IN THE FLINDERS RANGES, SOUTH AUSTRALIA: A PRELIMINARY REPORT.

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The Flinders Ranges region in South Australia contains a wealth of good stratigraphic exposures of late Quaternary fluviatile, aeolian and lacustrine sediments. There have been no detailed studies of late Quaternary erosion and deposition in this region since the pioneering studies conducted by G E Williams over 20 years ago on the piedmont deposits and palaeosols along the southwestern flanks of the ranges. A reconnaissance survey in July 1995 by myself and Dr D A Adamson along the length of Brachina Gorge and several other gorges in the northern and central ranges revealed a complex suite of late Quaternary alluvium, calcareous tufas, aeolian dust mantles, finely laminated lacustrine sediments, calcretes, palaeosols and colluvial gravels. Preliminary Accelerator Mass Spectrometer (AMS) dates on very small carbon samples collected in July reveal that the widespread reddish-brown alluvial sandy clay loams which form the main valley-fill unit within the mountains were accumulating during the height of the Last Glacial Maximum. The relevant dates are 20 840 ± 90 BP (Beta-84141) and 20 320 ± 90 BP (Beta-84140). The alluvial unit is capped by a distinct dark brown palaeosol, which was in turn overlain by two younger, coarser-grained alluvial units prior to the recent phase of incision. Twelve core samples were also collected for thermoluminescence (TL) dating and optically-stimulated luminescence (OSL) dating, and preliminary results are entirely consistent with the AMS dates but it will be some months before the final TL ages are available.

A second reconnaissance survey by myself, Dr D.A.Adamson, Professor J.R.Prescott and Mr Bryan Cock in December 1995 enabled us to collect additional samples for TL and OSL dating, and to carry out scintillometer readings of the total gamma dose rate as well as of background concentrations of potassium, uranium and thorium at each of the sites from which core samples were collected. Work is now in progress on all of these samples.

In addition to excellent stratigraphic exposures of late Quaternary sediments, another advantage of working in the Flinders Ranges is the very clear and regular variation in Precambrian and Cambrian bedrock geology from quartzite to limestone to argillite. Preliminary inspection of the late Quaternary fine sandy clay alluvium immediately overlying Precambrian quartzites was strongly suggestive of reworked wind-blown dust. This hypothesis needs rigorous testing, but is consistent with the pioneering work of Jessup on the desert soils of South Australia. The apparent lack of any change in mineralogy, colour, grain-size and micro-fabric across a lithologically diverse Precambrian substrate also accords with an allochthonous origin for this alluvium. The importance of late Quaternary aeolian dust accession for piedmont sedimentation elsewhere in semi-arid Australia is becoming increasingly recognised. Furthermore, there are encouraging signs that better chronometric control of desert dust in marine cores off the coast of Australia will enable us to correlate variations in dust storm activity on land to broader regional changes in climate and in oceanic circulation.

We plan to test the hypothesis that the **widespread reddish-brown alluvium** which comprises the **dominant valley-fill formation within the mountains is largely made up of reworked wind-blown dust.**

A second hypothesis is that **valley aggradation and dust deposition** in the Flinders Ranges were associated with a late Pleistocene regional climate which was (at least seasonally) effectively wetter than the present-day semi-arid climate.

A third hypothesis is that **deposition of wind-blown dust mantles** within the Flinders Ranges **altered the runoff regime** of the hillslopes and valley bottoms and was instrumental in promoting widespread aggradation by increasingly less integrated and less competent drainage systems.

A fourth hypothesis, prompted by our December 1995 reconnaissance, is that the **upper limits of valley aggradation are controlled by the elevation of rock-cut benches and pediments within the major valleys.**

A GEOMORPHIC RECORD OF CLIMATE CHANGE DURING THE LAST GLACIAL CYCLE FROM THE CONDOBOLIN AREA, CENTRAL NEW SOUTH WALES

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The Bogandillon Swamp is in the transition zone of the Lachlan River between the Eastern Highlands to the east and the Riverine Plains to the west. It lies in a pocket of the Lachlan River floodplain closely enclosed on three sides by bedrock ridges. The swamp is filled by floodwaters from the Lachlan River. Multiple shorelines, two clay lunettes, and truncated fans are present, and the higher ground is draped by red fine sandy clays similar to aeolian dust deposits described elsewhere on the margins of the Riverine Plains.

The above deposits represent a record of landscape response to climatic change from the highlands to the arid zone in the west. Water-filling of the basin parallels Lachlan River flow and hence runoff and groundwater conditions in the highlands and highlands margins. Shoreline development, clay dune formation, slope mobilisation and carbonate pans reflect local conditions. Dust deposits reflect both arid conditions to the west and local depositional conditions.

Salient points indicated by preliminary results are:

Oxygen isotope Stages 5 and 3 are wet; Stage 4 is a major dry phase, along with Stage 2.

After the glacial maximum, wet conditions impacted in the Lachlan River highlands catchment almost immediately (ca 17 ka C14 years), followed by the local area, then areas to the west.

Hydrological conditions altered drastically after the glacial maximum. With initial Lachlan River recovery, powerful throughflow possibly driven partly by high groundwater resulted in dissection of the basin when inflow and outflow channels were nearly joined. Subsequent low flows filled the basin with clays, resulting in successively smaller lakes and an infilled outflow channel. These latter conditions contrasted with maintained high lake levels and powerful outflow channels during previous wet period Stage 3 and perhaps Stage5.

The impact of local post-glacial amelioration resulted in the most significant features within the basin. Widespread slope mobilisation was unique to this time. Reworking of this coarse material resulted in high sand and gravel shorelines and a lake bordering dune that dominate the topography of the basin.

Source Bordering Dunes of the Wagga Wagga Area, New South Wales; Chronology and Stratigraphy

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Source bordering dunes are common on all the major river systems (both past and present) of the Murray Basin. With few exceptions the dunes are relict features from the Late Pleistocene and early Holocene. Previous work on these dunes has described the sediments ie the Cobram Sands (Brown and Stephenson, 1991), the modern soils, ie the Sandmount Series (Butler, 1942), the soil stratigraphy (Beattie, 1972) and the chronology (Bowler, et al ,1978).

In the Wagga Wagga area a large scale map of these sand bodies has recently been published (McDermot and Chen, 1996; Owens, 1996). Detailed work is presented here for three of the local dunes: Yarragundry, Glenfield and Clarendon. Sedimentary, pedologic and stratigraphic data for these dunes were collected. Clay bands, which are so common a feature of the lower part of the soil profiles and the underlying parent materials of source bordering dunes of the Murray Basin, were examined using micromorphology. A thermoluminescence dating program provides an absolute chronology.

The age of formation of the three dunes, based upon TL dating, falls into three periods: 80 to 120 ka BP (78.5±7.6; 86.6±25; and 111±22), 50 to 60 ka BP (49±6.3; 53.6±5.1; and 57.6±5.9) and 19 ka BP (19.1±1.5). These sets of dates can be correlated with three of the phases of stream activity recently proposed for the Riverine Plain: the Kerarbury, the Coleambally and the Yanco (Page, Nansen and Price, 1996). The origin of the clay bands of these source bordering dunes is suggested. The presence of sodic clay bands within the dunes is used to support a model of regional aeolian accession of saline, calcareous loessic clay aggregates (parna) onto the sand bodies during their formation. The dune stratigraphy and associated underlying/onlapping fluvial units are correlated with the soil stratigraphic units proposed by Beattie (1972).

Dust records in the Pleistocene sediments of Fraser Island: palaeoclimatic reconstruction of wind erosion over the last 400ka.

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ABSTRACT

Pleistocene lake sediments from a relic perched freshwater lake on Fraser Island have been found to date back ca.400ka, passing through at least four glacial cycles. This sequence is one of the three longest terrestrial records of environmental change in Australia and the contained evidence of vegetation, fire and lake level changes (Longmore and Heijnis, 1995) and is an invaluable contribution to palaeoclimatic reconstruction.

Continental aeolian dust from extreme wind erosional events has been measured in modern atmospheres (McTainsh, 1989; Knight *et al.*, 1995) and deep sea cores (Hesse, 1994), but the terrestrial record of wind erosion during the Pleistocene is sparse. We will report on a pilot project to determine the presence of aeolian dust from extreme wind erosional events in the past in the sediments of Fraser Island lakes. Due to the highly weathered, siliceous nature of the dune sands forming the Island and the highly organic nature of the lake sediments (80-95% LOI), these are some of the few terrestrial sequences that permit separation of aeolian dust from catchment erosional materials. In addition, chemical analysis of the extracted dust will allow the source of the entrained material to be determined and thus the wind regime during the last 400ka. The source and abundance of the material will be compared to marine cores to establish differences in provenance and rates of dust deposition; and to determine whether correlation with deep sea oxygen isotope records of glacial sea level fluctuations is possible. The separation of dust from this terrestrial sequence is a major achievement and potentially may make a significant contribution to global palaeoclimatic models.

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RECENT LANDSCAPE EVOLUTION IN WESTERN N.S.W.

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This paper presents new evidence for geomorphic change, and a model for explanation of that change, in the rangelands of western N.S.W. in the last 200 years under the impact of a grazing land use dominated by domestic and feral herbivores (sheep, cattle, rabbits, goats, etc).

It is widely recognised that both wind and water erosion have been enhanced by changes to land cover which took place when sheep and rabbits were introduced into western NSW in the late 1800s. Topsoil loss, surface scalding, rilling, gullying and wind drift were initiated by the reduction in groundcover and disturbance to topsoils caused by grazing and trampling. This in turn affected the hydrologic regime of the catchments, such that surface runoff was promoted at the expense of infiltration, topsoils were eroded off the slopes and vegetation was further diminished by reduced soil moisture. The exposure of mulga tree roots, and lichen levels on rocks scattered over the slopes indicate that up to 15cm of topsoil has been eroded off the hillslopes in catchments at Fowlers Gap in the Barrier Ranges north of Broken Hill, N.S.W. (P. Mitchell, pers. comm.).

The finer fraction of the eroded topsoils was washed out of the uplands. The coarser fraction mostly remained in the form of a layer of red sandy sediment spread over former floodplain deposits in the valley floors. Evidence for the post-European age of these red sands is given by the presence of European artifacts within this layer and Aboriginal hearths below it. Three radiocarbon dates, (350+/-50 [Wk-4197] from Fowlers Gap. and 220+/-50 [Wk-3147] and 420+/-110 years BP [Wk-3141] from Mootwingee, in the Bynguano Ranges northeast of Broken Hill) for charcoal from hearths located at or just below the boundary of the red sands and the sediments below, provide a minimum age for the sediments into which the hearths were excavated. Since they must predate the red sands which bury them, this suggests that the surface red sand layer is of recent origin i.e. less than 200 years old.

The next phase of hydrogeomorphic change was incision of stream channels and their subsequent enlargement through channel widening and knickpoint retreat. Along Homestead Creek at Fowlers Gap, evidence for major channel change is in the form of remnants of sediments of narrower, more sinuous paleochannels occupying cut and fill structures now transected by the wide, flat-floored trench ('arroyo') of Homestead Creek. Monitoring of bed elevation and bank collapse indicates that the contemporary channel is widening and incising, with serious consequences for roads, watering points and other infrastructure. Along Sandy Creek to the north, the post-European sediments are represented by red sandy overbank deposits overlying fine grained former pool sediments into which the present channel is now incised.

At Mootwingee also, the contemporary channels are now entrenched below the former alluvial surfaces. Channel enlargement and knickpoint retreat along Mootwingee's Homestead Creek has been monitored since 1990 by Dr Dan Witter, the NSW NPWS Western Region archaeologist. The channel has widened in places by up to 400% over that time period, and knickpoints have retreated by as much as 87 metres in a single runoff event. Bank undercutting and gully head retreat are here too threatening the continued existence of roads and the camping area, and areas of important cultural value, such as the recently excavated ceremonial site next to Giles Creek inside the Historic Site (Fanning, Witter & Mitchell, in prep.).

These are not isolated occurrences: other researchers in the region have reported similar changes, initiated by channel incision. which are still working their way through the system via channel enlargement and knickpoint retreat. How long they will continue to do so is difficult to predict but it may be decades to hundreds of years. This has significant implications for land management in the region.

A RE-EVALUATION OF THE STRATIGRAPHIC SIGNIFICANCE OF DURICRUST INTER-RELATIONSHIPS IN THE BROKEN HILL REGION, WESTERN NEW SOUTH WALES

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Introduction

Silcretes, ferricretes, calcretes and gypcrtetes have all developed during the landscape history of the Broken Hill region. The co-existence of a variety of duricrust types provides an opportunity to examine their inter-relationships and consider their stratigraphic significance.

Interpretations relating the occurence of particular duricrust types to specific palaeoclimates, palaeosurfaces (and weathering profiles), and related stratigraphic frameworks have been widely adopted. Many studies assigned a single age to envisaged continental "laterite" and silcrete forming events with the widespread acceptence of ages such as Miocene and Pliocene as the age of laterite formation, and a late Eocene to Oligocene period of silicification (e.g. the "Cordillo silcrete"). As a result duricrusts are often used as morpho-stratigraphic markers, with specific chronological connotations. In contrast, evidence from the Broken Hill region suggests that the development and modification of duricrusts has occurred throughout the evolution of the landscape in specific sites in response to local environmental conditions. Caution is therefore needed when using duricrusts as morpho-stratigraphic markers.

Silcretes

Silcretes of various types and ages occur in both topographically inverted fluvial sediments (of various ages) and adjacent saprolitic bedrock. Both pedogenic and groundwater types occur as well as complex polygenetic types consisting of several generations of silicified material (such as earlier formed pedogenic silcrete nodules that have been re-cemented within later groundwater silcretes). Detrital silcrete clasts also occur with younger silicified fluvial sediments. The distinction between pedogenic and groundwater silcrete types is important when determining the possible stratigraphic significance of silcretes. Pedogenic types have mostly occur in the upper parts of fluvial sequences and represent silicification of surficial pedogenic surfaces, whereas groundwater types often develop within the regolith profile, particularly along hydromorphic barriers. Several groundwater silcretes may develop in the one profile, some possibly forming similtaneously while others may represent changes in groundwater levels over time. Surface lags consisting of pedogenic and groundwater silcrete clasts continuously cover apparent silicified palaeosurfaces. In many cases, however this lag represents a surficial armour derived from localised silcrete exposures and spread over breakaway backslopes or as residual debris that has accumulated during landsurface lowering over gently undulating plains.

Ferricretes

Ferricreted saprolite, sediments and slabby and complex pisolitic ferricretes occur in the region. These show a variety of inter-relationships with silcretes and occur in different field settings and host material of variable ages. Ferricreted mottles occur in weathered bedrock often underlying silicified fluvial sediments containing detrital mottle fragments. Some ferricreted sediments occur within or marginal to silcreted fluvial sediments and represent contemporaneous silicification and ferruginisation. Other ferricretes occur as slabby or pisolitic detrital ferricrete clasts within valleys incised into the silcreted fluvial sediments and clearly post-date the silcretes and other ferricretes. The stratigraphic relationships between ferricretes and silcretes is much more complex than many previous studies have suggested.

Calcretes and Gypcretes

Calcretes are widespread as pedogenic and groundwater duricrusts across the landscape in the Broken Hill region. They are best developed in areas characterised by thick accumulations of aeolian sediments as well as in alluvium associated with the present drainage system. Groundwater calcretes frequently occur within thick alluvial sequences especially along the hydromorphic barrier coinciding with the alluvium / bedrock interface. The development of calcretes most probably reflects the increasing aridity in this region towards the later part of the Cainozoic. Gypsum mostly occurs as disseminated crystals throughout the soils and recently deposited alluvium. In some parts, however, they may form accumulations and duricrusts tens of centimetres thick. Although largely related to the present semi-arid climate, some gypsum accumulations may also be directly related to the weathering of sulphides.

LAND SURFACES AND 'LATERITES' IN SOUTHERN SOUTH AUSTRALIA

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Ferruginous and aluminous rich crusts, sometimes associated with weathered, mottled and bleached materials, loosely regarded as 'laterite' by many have a widespread distribution in southern Australia, although commonly their collective area of coverage is not as widespread as indicated on many geological maps. Critical to the interpretation of 'lateritic' materials is their association with landsurfaces. In recent times there has been conflict about the interpretation of lateritic materials, specifically about their antiquity and their use as morphostratigraphic and palaeoclimatic indicators.

Views include the possibility of the preservation of Mesozoic 'laterite' in a subaerial environment and in pristine condition for some 200 Ma, that it can be used as an excellent morphostratigraphic marker over widespread areas, and that it indicates widespread formation on a subdued land surface during humid and torrid tropical conditions. Ferricrete crusts are relatively rare in many areas, and are often absent above pallid and/or mottled zones, suggesting the erosional truncation of former complete 'laterite profiles'. However, perhaps the crusts had never developed. An alternative suggested to a former uniform blanket of 'laterite' over large areas, is that different types of ferricretes, mottled and bleached zones may have developed in specific sites in response to local environmental conditions. Stratigraphic evidence suggests that ferricrete development, mottling and bleaching was an on-going process throughout the Mesozoic and Cainozoic.

Ferricretes appear to be younger than underlying 'companion materials' and are not mono-genetically related to them. Diverse forms of ferricrete appear to have developed in different palaeo-environments through the operation of a range of processes. For example, some have formed by the in situ weathering transformation of pre existing iron-rich minerals. Some other ferricretes developed as a result of the transport, accumulation and cementation of ferruginous materials such as pisoliths and fragments of mottles.

The chemical and mineralogical characteristics of 'lateritic' materials in southern Australia reflect various modes of formation. Different facies of ferricrete (vermiform, pisolitic, nodular vesicular to massive, slabby and ferruginised bedrock and ferruginised sediments) display differing chemical and mineralogical compositions that reflect environmental conditions during formation. Consequently the view is taken that the detailed characteristics of the different ferricrete morphologies represent 'tape recordings' of their epigenetic histories, the unravelling of which may be accomplished by careful study of their attributes.

Evidence of different facies of ferricrete having formed coevally in different parts of the same landscape and the occurrence of identical ferricretes on landsurfaces of disparate ages, restricts the usefulness of ferricretes as morpho-stratigraphic markers, except in the coarsest sense. No direct indication of age derives from ferricrete morphology, chemistry or mineralogy, as similar ranges of weathering and ferruginous materials occur on both lowland and summit surfaces. However, ferricretes with the greatest mineralogical diversity (e.g. hematite, goethite, maghemite, gibbsite, boehmite and kaolinite) appear to have more complex histories of evolution than do ferricretes and mottles with simple iron oxide mineralogies (e.g. goethite in ferruginised clastic sediments, and hematite in mottles).

In some cases there is the progressive exposure of inherited weathering features such as kaolinised and mottled zones, which become modified by present day weathering processes through exposure, hardening and disintegration at the surface where iron-rich segregations have accumulated and formed lags during landscape downwasting and planation surface development. Lateral transport often plays an important role in these situations.

TOWARDS A MODEL OF LANDFORM EVOLUTION ON AN IGNIMBRITE TERRAIN: MAMAKU PLATEAU, NEW ZEALAND

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Quaternary volcanism in the Taupo Volcanic Zone, North Island, New Zealand, has produced numerous ignimbrite sheets (pyroclastic flow deposits), which cover much of central North Island. Recent models of landform evolution have largely ignored ignimbrite landscapes. However, the presence of these extensive, thick, dated, ignimbrite sheets provides an excellent landscape for the study of landform sensitivity and change. The Mamaku Plateau, North Island, New Zealand, is such a landscape, and a model of landform evolution is being developed for this ignimbrite plateau. The Mamaku Plateau covers an area of 1700 km^2 and slopes gently towards the north and towards the west. It ranges in elevation from 200 m to 700 m a.s.l. The main body of the Mamaku Plateau consist of the Mamaku Ignimbrite which is the youngest (0.22-0.23 Ma)[1,2] of the large, welded, sheet-forming ignimbrites from the Taupo Volcanic Zone.

Landform analyses using modern GIS tools, in addition to traditional stereoscopy, revealed three distinctive landform types on the Mamaku Plateau: in the west the plateau is highly dissected by deep, steep, wide valleys; towards the north it is only partly dissected by deep, steep, narrow valleys; and near the centre an undissected landscape is present on which isolated 20 m-high rock outcrops (tors) occur. A well documented coverbed sequence of tephras, paleosols and loess beds[3] allows the different landforms of the Mamaku Plateau to be dated using tephrochronology. A nearly complete coverbed sequence is present on the interfl-uves between the valleys in the northern and western parts, thus indicating a long period of stability on these interfluves. However, very few tephra or loess deposits are present on the valley sides indicating a continuing processes of valley formation and/or valley widening. The floors of the valleys in the west of the plateau feature pre-Mamaku erosion surfaces. Such surfaces indicate that the Mamaku Ignimbrite has been removed from the valleys and that the valleys are in the same phase of dynamic equilibrium as they were prior to the eruption of the Mamaku Ignimbrite.The valley floors in the north of the plateau are being deepened at present. The centre of the plateau is covered with a post-14,000 BP tephra sequence. The pre-14,000 BP tephra and loess deposits are absent, indicating a pre-14,000 BP erosional episode.

The Schmidt hammer test, which measures the rebound, and the slake durability test, which essentially measures the abrasiveness, were both used as indicators of ignimbrite strength. The Schmidt hammer test produced non-consistent results, which proved to be unsuitable for this study. The slake durability test, however, showed a wide range of results from 15% to 98% (percentage of ignimbrite left after two slaking cycles). Predominantly low values (20-40%) were found in the west of the plateau. A distinct change in morphology coincides with an increase in slake durability values (50-80%) towards the centre of the plateau. High values were found in the steep narrow valleys in the north of the plateau (80-98%). A relationship has been developed between valley morphology and ignimbrite strength using the slake durability data.

A model of landform evolution on the Mamaku Plateau is being developed through the integration of the landscape activity analyses, the ignimbrite strength analyses, and the land-forming processes. Each major ignimbrite eruption destroys the antecedent dynamic equilibrium established at a location. After deposition of the ignimbrite, valleys start to form and the landscape starts to 'work' towards a new phase of dynamic equilibrium. The interfluves between the valleys are areas of accumulation and they quickly enter a new phase of dynamic equilibrium. Each successive minor eruption adds tephra layers on top of those previously deposited; soil formation takes place in between these depositional events. The centre of the plateau is an exception to this pattern, and the model of Kennedy[3] is suitable for this area. The Mamaku Ignimbrite in the west of the plateau was emplaced as a relatively easily erodible deposit. Consequently there has been sufficient time, since 0.22 Ma, to re-erode the valleys to their previous depths: the landscape has overcome the catastrophe of the deposition of the Mamaku Ignimbrite and has reached a new phase of dynamic equilibrium. In contrast, the upstream parts of the valleys of the west, and the entire valleys in the north of the plateau, are still being deepened at present. The Mamaku Ignimbrite at these locations is resistant enough to prevent re-establishment of the previous state of dynamic equilibrium within 0.22 Ma: this landscape is thus still recovering from the catastrophe that was caused by the emplacement of the Mamaku Ignimbrite.

[1](1995) Geology. 23. 13-16. [2](1994) Geophysical Research Letters. 21, 1695-1698. [3](1994) Geomorphology. 9, 97-115.

THURSDAY 3RD OCTOBER

LAVA INFLATION LANDFORMS IN THE TOOMBA AND UNDARA BASALT FLOWS, NORTH QUEENSLAND.

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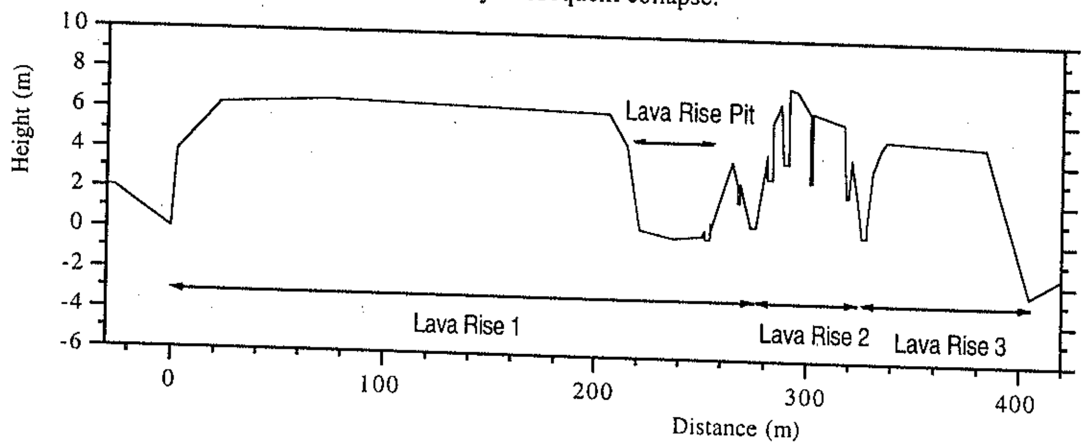
The formation of volcanic landforms by lava inflation processes has only recently been recognised. Lava inflation was first highlighted by Walker, (1991, Bull. Volc. 53, 546-58), and active inflation of lava sheets have been documented by Mattox et al (1993, Bull. Volc. 55, 407-413) and Hon et al (1994, Geol. Soc. Am. Bull., 106, 531-70).

The Toomba and Undara basaltic lava flows contain excellent examples of landforms produced by lava inflation, both in terms of the size and extent of the landforms produced and their degree of preservation. Landforms include lava rises and tumuli, lava rise pits, lava inflation crevasses and an enigmatic structure referred to here as lava rise caves.

Lava rises are formed when a thin (< 1 m) lava flows develops a crust and is then inflated by hydrostatic pressure of molten lava underneath (Walker, 1991). They have steep sides, commonly between 45° and 90°, with a relatively flat top. Lava inflation crevasses are formed at the break of slope between the sides and the top surface. Crevasses are also common in the top surface. Tumuli are formed in a similar manner to lava rises, but are oval shaped up-wellings centred on a relatively small focus, rather than the plateau form of lava rises. Tumuli typically have a central crevasse or several radial crevasses. Where the crust completely solidifies through the initial thin flow, inflation is not possible. These regions therefore remain at their original level, while the flows around them inflate. This produces depressions in the final lava flow surface. Such depressions have previously been interpreted as due to collapse. Lava rise caves are bell-shaped cavities formed in the inflating lava.

The Toomba basalt flow is a long (120 km), flow with ubiquitous lava inflation structures. As it is only 13,000 years old (Stephenson et al, 1978, 3rd Aust. Geol. Conv.), surface features are well preserved. Continuous ropy lava can be seen on the floors of pits, on the slopes of rises and over the tops of lava rises, indicating an original uniform surface prior to inflation. Lava rises are typically 5 - 10 m high, but can reach over 20 m. Particularly good examples of three parallel lava rises formed in a 5 km section where the Toomba flow was prevented from entering the channel of the Burdekin river by the presence of the older Birdbush basalt flow. A measured transect of these lava rises is shown below. Lava rise pits are up to 22 m deep, and the larger pits are over 60 m wide and nearly 300 m long. No lava tube caves have been found in association with any of the lava rise pits or caves, pointing to their formation by inflation of the surrounding lava, rather than by subsequent collapse.



The Undara flow, at 190,000 years old (Griffin & McDougall, 1975, J. Geol. Soc. Aust, 22, 387-96), is somewhat more degraded, but, by comparison to the Toomba structures, it can be seen that lava inflation processes were also prominent there. "The Wall" section of the flow, for example, is interpreted as a particularly long lava rise. Lava tubes at Undara do not appear to have formed in association with the large, vegetated depressions, that are here interpreted as lava rise pits. Instead, the lava tubes can be seen to divert around the pits that were formed by the earlier inflation.

THE THERMAL HISTORY OF THE LAURA BASIN, NORTH QUEENSLAND, AND IMPLICATIONS FOR DENUDATION OF THE REGION

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The Laura Basin in northern Queensland contains over 1 km of Middle Jurassic to Early Cretaceous fluviatile and shallow marine strata, with a thin covering of Cainozoic terrestrial sediments. Vitrinite reflectance (VR) values from samples throughout the sequence range from 0.6-1.0%Ro, and show no correlation with depth. This data indicate that the entire sequence has been heated to temperatures in excess of 100°C, and the heating cannot be due solely to burial.

The timing of this heating may be constrained by apatite fission track analysis (AFTA) on samples of Palaeozoic basement to the south of the Laura Basin; one of these samples directly underlies the Laura Basin sediments. These data show that the samples reached temperatures in excess of 110°C prior to cooling at 80-100 Ma. Additional AFTA data is presently being obtained from the Laura Basin sequence.

In order to reach the temperatures indicated by both the VR and AFTA data, the samples must have been buried by about 2.5 km of sediment, assuming the present geothermal gradient of 37°C/km. If the gradient was 60°C/km, the maximum believed reasonable for passive margins apparently unaffected by intrusions or volcanism, about 1.5 km of sediment must have covered the area. This degree of burial is more or less consistent with the low porosity of sandstones in the sequence (12-16% at depths of 650-1050 m).

The cooling recorded by the AFTA data could represent the removal of this overlying sediment by denudation. Since the denudation occurred at the latest at around 80 Ma (Late Cretaceous), the sediment eroded must have been Late Cretaceous in age. This is intriguing, because no onshore basins anywhere in Australia contain any significant thickness of Late Cretaceous sediments. It has been proposed that during this time Australia lay on a geoidal high, so that compared to other continents flooded by Late Cretaceous eustatic high sea levels, Australia was topographically elevated. Thus it is unlikely that the Laura Basin ever contained a substantial thickness of Late Cretaceous strata.

The VR and AFTA data cannot be easily explained by burial alone, and alternative explanations may be required for the palaeotemperatures recorded. The heating mechanism involved is uncertain; perhaps there was a relatively short-lived thermal pulse, that heated the groundwaters within the sediments. No matter what the mechanism, it seems that in the Laura Basin the VR and AFTA data cannot be used as accurate guides to the amount of burial and denudation in the region. This conclusion is not applicable to other areas where the geothermal gradiant can be constrained.

Evidence for downwarping on passive margins

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Here we examine the idea that some passive continental margins are a former land surface - the palaeoplain - which has been warped, producing a basal unconformity offshore where it is downwarped, and the marginal swell on land where it is upwarped. The palaeoplain is an ancient landsurface of fairly low relief.. It is not only found in the highlands of Victoria and New South Wales, but is also the high plain or plateau in Africa, India, Brazil, Scandinavia and elsewhere on passive margins. On the southern continents it is essentially the pre-breakup landsurface of Gondwana, with all the irregularities that existed at that time.

Generalised contours indicate the downwarped surface in a few areas. Examples are found in South Africa and the Shoalhaven area of south east Australia. In a few areas the palaeoplain can be traced across intervening plateaus to a coastal facet and so to the sea. Such downwarping is not self evident in theory, and indeed the commonly accepted model, championed by King (1955) is of successive pediments, slope retreat and uplift of a series of steps.

One of striking features of the eastern margin of the Australian continent is the difference between drainage patterns west of the Great Divide and those to the east. To the west the patterns are simple dendritic, with the tributaries joining the main river at acute angles that point in the direction of flow. To the east, on the other hand, the rivers are anything but simple; they commonly rise near the coast and flow inland before turning to flow out to sea. Some start near the top of the Great Escarpment and again flow inland before turning and flowing east over the Great Escarpment, often as waterfalls. It is not always appreciated that major drainage patterns are older than tectonic movement on passive margins, but this is so, and can be used to test the nature of movement. In general the results show that downwarping has occured. .

The palaeoplain is preserved on the high plateau and, seaward of the caost, as the basal unconformity, but as these were once continuous there should be remnants of the palaeoplain near the coast. This will have been largely removed by later erosion near the coast, but in places there will be patches of preserved palaeoplain near sea level. They will be preserved especially between major rivers, and tend to be rather triangular, akin to planezes on a volcano, or flatirons on dipping strata; we term them 'coastal facets'. Such coastal facets will retain old weathering profiles, and perhaps old lava flows or other igneous rocks. Coastal facets have already been reported in the literature, and even mapped, in the Bega area, and near Port Macquarie.

GEOMORPHIC EXPRESSION OF FAULT BLOCK MOVEMENT IN THE HIGHLANDS OF EASTERN VICTORIA.

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Ever since the concept of a unified Plio-Pleistocene uplift of the Eastern Highlands was invalidated by evidence of Tertiary tectonic stability of the southeastern highlands plateau, cases of apparent major mid- to late Cainozoic tectonic reactivation within the highlands have not featured strongly in geomorphic literature, and not without controversy. The current paradigm maintains that the majority of the height of the highlands was established by the late Mesozoic, possibly related to the rifting and breakup of Gondwanaland. Zones of deep fluvial incision within the highlands, including at the Great Escarpment and in eastern Victoria, have been explained by headward migration of river incision, adjusting to the new base levels created by Cretaceous rifting.

On closer examination the pattern of fluvial incision in the east Victorian highlands is not consistent with simple margin-to-divide incision in the style that has been supposed for the Great Escarpment. Apart from cases of obvious differential erosion, spatial variations in the depth and timing of fluvial incision can be related to movements of major fault-bounded blocks. This paper examines the relationships between fault block activity and fluvial incision, sediment composition changes and depths of weathering for the Bogong and Dargo High Plains region and the Omeo Geocol.

Fault block morphology in this region is dominated by a small number of large faults, with displacements of hundreds of metres, that bound "blocks" in which regional tilting and minor faulting (<200m displacements) occur. Where demonstrable, faulting is primarily reverse. Of the major faults the Tawonga Fault is the best known for evidence of Cainozoic reactivation (Beavis, 1960; Ollier & Wyborn, 1989; Morand & Gray, 1991, 1992). Displacement is over 600m with relative upthrow in the south. Southeasterly regional tilting occurs behind the Tawonga Fault and has caused a change in drainage directions from the original north-south aligned topography of the Oligocene basaltic volcanic province. Minor faulting has taken place in the tilted zone, including reactivation of the Kiewa Fault, which has displaced lava flows by 90m since the Oligocene.

Depths of incision vary according to the position within the fault blocks. Where regional tilting is predominant, rivers have incised an additional 400m to 600m below the original Oligocene relief of 200m to 370m. Close to the Tawonga Fault the depth of adjacent incision below the subvolcanic gravels increases to 970m. Strath terrace levels within the major river valleys also vary according to their proximity to faults.

Sediment composition changes have taken place since the Oligocene. In the Oligocene landscape sediments are quartz rich, suggesting derivation from a weathered mantle, although closest to the Tawonga Fault some lithic sediments had already been transported. The depth of weathering below the volcanics is unusually shallow to almost non-existent closer to the Tawonga Fault. Regolith stripping and tectonic activity may have already been taking place during the Oligocene. Also in the north the basal contacts include both bedrock streams and impeded drainage, so that even though the subvolcanic topographic depression is aligned north-south, a single continuous river may not have existed by the time of the volcanic eruptions. Gravels of the strath terraces and present river bedloads are nearly entirely lithic (95-98%), confirming bedrock incision well below the original weathered mantle.

The Omeo-Benambra "geocol" region is areally the lowest fault-bounded block. Dissection is not extensive, the weathered mantle is deeper and intra-block fault scarps and impeded drainage are preserved intact. It provides a control area for interpreting the high plains landscape.

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BASALT AND SUB-BASALTIC SEDIMENTS IN THE CLYDE RIVER VALLEY, NSW.

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Old alluvial sediments occur along the Clyde River in the Brooman area, north of Batemans Bay in Southeast New South Wales. They were first described a century ago by gold prospectors. Geological reports of the time failed to note that basalts overlie some of the deposits and consequently the basalt has not been previously mapped or described. The gravels are quarried for road and building materials, but there are no recent published descriptions.

The sediments and basalts are exposed along the ridge crests of steep hills over a ten kilometre stretch of the middle reaches of the Clyde River valley. The basalt, of alkali olivine composition, flowed down the ancestral Clyde River valley and now constitutes a 10 metre thick sheet. Alluvial sediments consisting mainly of poorly sorted polymictic conglomerate are around 10 metres thick and contain rounded quartz and Palaeozoic sandstone clasts up to boulder size in the sandy matrix. The alluvial sediments mostly overlie folded Lower Palaeozoic metasediments of the Lachlan Fold Belt, but in places they overlie Permian Sydney Basin rocks. The base of the sediments occurs about 85 m above the present valley floor.

Basalts in the surrounding Sassafras, Ulladulla and Moruya areas have published K-Ar ages of 26-40 ma. If this basalt is of a similar age, the indicated rate of lowering of the valley floor since extrusion is 2-3m per ma, contrasting with many other localities, where downcutting since basalt extrusion has been minimal.

This locality is important to the understanding of the evolution of the Southern Highlands and Great Escarpment, as one of the few valley basalts which occur close to the incised zone at the foot of the Great Escarpment. This study is currently in the preliminary stages and future work will include detailed mapping and dating of the basalts and underlying sediments.

GEOMORPHOLOGICAL EVOLUTION OF THE LAKE BATHURST DRAINAGE BASIN, NEW SOUTH WALES

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Geological background

Lake Bathurst drainage basin with an area of 115 sq. kms is situated about 30 km south of Goulburn within the Southern Tablelands of New South Wales. In regional geological terms the basin lies in the southern part of the Lachlan Fold Belt. The bedrock consists of upper Ordovician quartz turbidites unconformably overlain by late Silurian shallow marine sediments and acid volcanics intruded by Devonian granite (" Lake Bathurst Granite") and dolerite dykes. Permo-Triassic sediments of the Sydney Basin resting unconformably across the Palaeozoic sequence are now confined to an erosional margin of resistant sandstone east of the Shoalhaven River. Crustal stability and a long period of subaerial weathering through the Mesozoic led the local region to attain a low relief landscape by the end of the Cretaceous. The Palaeogene is represented by fluvial and colluvial sediments cemented to ferricrete and silcrete, while Eocene basalt is capped by bauxite. There is no definite evidence for a Neogene squence. The Quaternary is represented by fluvial, colluvial, lacustrine, strandline and aeolian sediments variably modified by pedogenesis. Drilling indicates the Quaternary sequence may locally exceed 40m in thickness.

Geomorphological evolution

The drainage basin lies along the watershed separating the Wollondilly and Shoalhaven catchments and is an elevated remnant of the ancient Shoalhaven Plain. It probably originated in the late Tertiary by drainage disruption caused by lowering of the base level of the Shoalhaven River and partial capture of the headwaters of Mulwaree Creek leaving a local perched base level of swamps and disorganised drainage.The separation of lake Bathurst drainage basin from Mulwaree fault scarp by Mulwaree Creek suggests the basin is unlikely to have formed by direct tectonic processes eg. a fault dammed lake. Alluvial aggradation by Mulwaree Creek across this area of indefinite drainage was probably the main process leading to basin closure. A late Quaternary history is evidenced by the catchment morphology and sedimentary sequence superimposed on the closed drainage basin. A late Pleistocene "lake full phase"is evidenced by the highest palaeoshoreline at approx. 680m ASL. The progressive reduction in size of this megalake is largely a function of climate change. High lake levels have gradually recessed to form a complex of smaller lakes eg. the Morass. with the coeval construction of beach ridges and palaeoshorelines below the 680m contour. It is probable that the wavebuilt sand barriers respond to periods of wetter climate while the clay lunettes are landforms relating to drier periods.

The timing of drainage basin initiation is poorly constrained. From evidence provided by ferricrete and bauxite, the age of the prior landscape preserved in the basin dates back at least to the Mid Tertiary and probably to the Cretaceous. Ferricretes are dissected by the modern drainage and at other places covered by Quaternary sediments. Rejuvenation of Mulwaree Fault followed by partial capture of the headwaters of Mulwaree Creek preceded the formation of the drainage basin. Evidence for renewed movement along old faultlines in the region is provided by the adjacent Shoalhaven Fault which cuts an Early Miocene basalt. From this meagre chronology it may be inferred that rejuvenation of the Mulwaree Fault is of a similar age with basin initiation even younger. At this stage there is no evidence for the preservation of Late Tertiary (Pliocene) sediments but a palaeomagnetic date of 780,000 yrs BP is an indicator of the length of the Quaternary sequence in the basin. Climatic oscillations associated with glacial episodes beginning at the end of the Tertiary may have provided the impetus for alluvial aggradation that finally led to the formation of Lake Bathurst and later the Morass. the radiocarbon date of 43,000 yrs BP from the western barrier suggests the lake basin existed prior to the last Glacial Maximum. It is perhaps noteworthy that the Lake Bathurst drainage basin may in part parallel the evolution of marshy depressions and lagoons eg. Breadalbane Plains and Wollogorong Lagoon to the north which are also sited in an area of disrupted drainage within the headwaters of the Lachlan catchment.

Changes to the pristine nature of the landscape over the last 170 yrs are associated European occupation. Dryland salinity (scalding) and gully erosion have occurred in response to tree removal and pastoral activity. Slope instability (minor landslipping) occurs along the inner lunette margin bordering the northern Morass. The trimmed inner margin of the western barrier at Lake Bathurst is due in part to groundwater discharge and degradation through sand mining.

HISTORICAL CHANNEL CHANGES ON THE MAJOR RIVERS OF NORTH-EASTERN QUEENSLAND.

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The behaviour of six major rivers flowing across the coastal plain of North-Eastern Queensland (Tully, Herbert, Houghton, Burdekin, Don, Proserpine) was examined on the basis of historical documentary data. Evidence regarding the pre-historic condition of these rivers was obtained from palaeochannels and bore-logs produced in conjunction with water supply, road and railway developments. Fieldwork was carried out in 1990, only a few years after the completion of the Burdekin Dam and prior to the completion of the Peter Faust Dam on the Proserpine River. Consideration was given to non-tidal and tidal reaches.

Active meander processes and avulsions were observed in the study area, and these are considered to be primarily natural processes. Because of the large size of the major rivers and high value land uses on the adjoining floodplains, lateral instability has become a significant management concern. No evidence of river metamorphosis since European settlement was found on the major rivers, unlike some smaller streams in this region which have undergone channel incision and associated morphological changes.

THRESHOLDS OF CHANNEL INITIATION IN HISTORICAL AND HOLOCENE TIMES, SOUTHEASTERN AUSTRALIA.

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Deep channels have repeatedly incised unchannelled grassy or swampy valleys across a diverse range of environments. Debate continues on the causes of channel initiation partly because work has concentrated on the chronology of incision to the neglect of studies examining the interplay of force and resistance. This paper argues that both the chronology of erosion and process studies provide valuable insight into the controls on channel initiation.

In southeastern Australia, the chronology of Holocene channel incision has been a subject of contention. Consequently, the first aim of this paper is to present an expanded chronology of gully erosion for the Southern Tablelands of New South Wales. The chronology suggests a previously unidentified period of accentuated gully erosion across the region between 4,000 and 2,000 y BP. However, no simple link is found between the palaeoclimatic evidence and processes of channel initiation. In historical times, gully erosion closely followed the introduction of modern agriculture to the region but again the processes remain poorly defined.

Consequently, flume experiments were conducted in an unchannelled valley to better understand both historical and Holocene channel initiation. Data on flow resistance and critical shear stress for scour were collected for natural and degraded vegetation covers, and used to predict the sensitivity of valleys to channel initiation. Combining this analysis with the chronology of erosion shows that in historical times gully initiation was more sensitive to degradation of valley floor vegetation than to changes in climate or increased runoff induced by clearing of forests. Processes of Holocene gully erosion remain less well defined but incision under past climates was achieved through either extreme events or with reduction in valley floor vegetation cover.

MEANDER CUTOFFS AS INDICATORS OF ENVIRONMENTAL CHANGE, LATROBE RIVER, VICTORIA.

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Assessment of the human impact on fluvial systems should be based on a sound knowledge of pre-impact channel conditions in order to accurately determine the magnitude and nature of channel changes. Detailed archival records of past channel dimensions, flow velocities, sediment and pollution loads, however, are unavailable for many rivers. Along meandering rivers, meander cutoffs offer an opportunity to somewhat redress this lack of data. This paper outlines the results of a case study of meander cutoff dimensions, stratigraphy and pollutant levels compared with archival data for the Latrobe River.

The meandering, sand-bed lower Latrobe River has been subject to considerable disturbance since European settlement, including: river de-snagging; clearing of woody riparian vegetation; channel widening; introduction of mining overburden and encouragement of numerous (65) artificial meander cutoffs. Pre-European channel dimensions were determined from meander cutoffs investigated in the field and compared with detailed aerial photo and channel survey data. Average bankfull widths have increased by almost 50% over pre-European values and the channel has incised by approximately 1 metre (an increase of 20% of bankfull depth). The dimensions of artificial meander cutoffs installed in the 1950-60s suggest that the major increases in channel width and depth occurred after the installation of the 1950-60s artificial cutoffs. Indeed, prior to the installation of artificial cutoffs even the largest flood on record was ineffective in causing channel change despite the channel banks being largely cleared of trees and shrubs at the time of the flood.

The infill stratigraphy of meander cutoffs can provide information on past sediment and pollutant loads of river systems. Comparisons between Latrobe River pre-European and historical age cutoffs reveal a change from silt-clay to sand dominated flood-load sediments which reflect historical increases in mean flow velocity, channel capacity and stream power. Substantially greater sedimentation rates in historical age cutoffs suggest that the volume of flood-load sediments carried by the Latrobe River has significantly increased since European settlement. Heavy metal levels determined in pre-European and historical age meander cutoffs indicate that levels of Cr, Ni, Cu, Zn and Pb have increased by 30 - 50 % over natural background levels since the turn of the century. Mercury (Hg) levels have increased to a maximum of 7000 % over background levels.

Meander cutoffs in Australia provide an excellent opportunity to investigate recent pre-European channel conditions. Baseline data on channel dimensions, sediment and heavy metal loads can be relatively easily determined and compared with existing channel conditions to determine the magnitude of human impacts on river systems.

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EUROPEAN IMPACTS ON DOWNSTREAM SEDIMENT TRANSFER IN COBARGO CATCHMENT, NEW SOUTH WALES

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The within-catchment distribution of bank erosion in Cobargo catchment, on the South Coast of New South Wales, is determined by the character and distribution of geomorphic process zones. Upland valley fills at the base of the escarpment represent substantial sediment source zones which have been incised to bedrock. Channels have subsequently overwidened, and are presently up to 8 m deep and 60 m wide for catchment areas < 10 km^2. Virtually all banks are eroding. Downstream of the sediment source zone, sediment transfer zones are characterised by partially choked, sinuous channels. Coarse sands stored in bedrock-confined point bars deflect flow to outer banks where colluvial footslopes are eroded. Approximately 50 % of banks are eroding in this section of the catchment. Other than the 10 km river reach upstream of the river mouth, the remainder of the catchment is a sediment throughput zone, confined within metasedimentary rocks. Sediment transfer is marked by fluctuations in channel bed elevation, with negligible bank erosion. The downstream 10 km of the catchment, along with the delta in Wallaga Lake, represent the sediment accumulation zone. Erosion is restricted to occasional concave banks in this reach.

Prior to European settlement of Cobargo catchment, upland valley fills were largely intact (ie unincised), and middle (transfer) reaches of the catchment comprised swamps. Vegetation clearance, along with disturbance and drainage of swamps, transformed discontinuous water courses into continuous channels. Working from a base-point of intact upland valley fills, almost 50 % of available material has been removed, contributing 2.9×10^6 m^3 of material to the lower catchment. Of this, roughly 65 % has been stored along Narira Creek, primarily along the channel bed and floodplain. This gives a total sediment contribution to the delta of 1×10^6 m^3. The crude sediment budget indicates that whatever catchment management efforts are applied in the sediment source zones of the upper catchment, sufficient materials are stored in transient storage units along transfer zones to maintain current rates of sediment throughput to the delta for several decades.

THE TIMING, EXTENT AND CAUSES OF POST-EUROPEAN LANDSCAPE EROSION IN THE UPPER MURRUMBIDGEE CATCHMENT IN NEW SOUTH WALES

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Catchment planning strategies and land management decisions related to the prevention of erosion of hillslopes and streams and the restoration of eroded areas have traditionally been based on certain assumptions, being;

- the majority of evident erosion is a post-European settlement phenomenon, and is;
- the result of catchment conditioning by clearing of treecover, the misuse of fire, ploughing and overgrazing by introduced stock including rabbits; and
- the accelerated post-European erosion is a continuing process.

Detailed historical studies have been carried out on the Southern Tablelands of NSW, particularly in the Murrumbidgee Catchment that lies upstream of Canberra. The writings and illustrations of explorers, settlers and others, together with relic evidence and original and later surveys have been examined to clarify the timing, extent and causes of post-European landscape erosion.

The results of the research questions some landscape management strategies that are based on the assumptions.

- The majority of erosion is indeed a post-European phenomenon. Drainage lines, including rivers incised rapidly after settlers arrived. Early writings indicate that this process was unfamiliar with it being described by one witness as *"perfectly astounding"* The term "erosion" was not in use, the process being described as *"excavations"* or *"torrents finding their way."*
- The removal of treecover can be discounted as a conditioning agent for the erosion. Areas settled were either grasslands or open woodlands. Where timber existed along main ranges it was described as being relatively open, with no understorey. Understorey in timbered areas increased and Eucalypt regrowth occurred once the regular low intensity burning practices of the Aborigines ceased. Broadacre ploughing was not carried out, although drainage of swampy areas, deliberate or otherwise, did cause some gullies to form. The first mention of erosion coincides with a period described by some as drought-stricken and during a time when warnings were being made of the effect of sheep, cattle and horses on the landscape. Kangaroo Grass *Themeda spp* all but disappeared within decades. Rabbits did not appear until much of the erosion had occurred. While exacerbating the problem, the rabbit was not a root cause.
- Aerial photographs show that the majority of hillslope gully networks were at their current extent by 1944. Relic evidence, such as bridge remains, indicate that many were in place well before the turn of the century. More recent evidence shows that most hillslope erosion is in a natural healing phase. Some major gullies, creeks and rivers are, however, continuing to actively erode, with, in some cases, the post 1950's rate being greater than that of the previous 100 years.

Historic evidence indicates that landscape management effort for erosion control needs to be targeted in major drainage lines identified as actively eroding. Treating gully networks that are rehabilitating naturally has limited cost efficiency. The historic evidence also suggests that extensive tree planting programs cannot be justified on the grounds of either erosion prevention or catchment restoration. If the lessons of the past are heeded, groundcover maintenance, with possibly the reintroduction of native species, is an area requiring major effort.

THE ORIGINAL FORESTS REVISITED - THE ROLE OF GEOMORPHOLOGY

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When non-indigenous people first came to Australia, what was the landscape like and how was it managed? In 1969, Rhys Jones coined the expression 'fire-stick farming' to describe the land management practices of the traditional owners. Jones argued that Aboriginal burning had altered ecosystems so that much of the open forest types were in fact artefacts of those fire regimes. According to a subsequent commentator, 'the eucalypt forest had ... a woodland structure', that is, 'large-boled, wide-crowned, widely-spaced trees over an open and largely grassy forest floor.' In recent times it has been asserted that this model applies 'all over Australia', and 'in every conceivable landscape.'

This presentation will firstly review the literature since 1969, and examine the more recent social, political and regulatory context of the 'open woodland' model. Secondly, the presentation will evaluate the model from a number of bases, including anthropological, climatological, ecological, pedological, and in particular, geomorphological.

Geomorphic evidence and reasoning has hitherto been under-utilised, misinterpreted or ignored in this debate. A number of case studies including from the Monaro region and the forests of south-eastern Australia will be used to clarify the environments to which the Aboriginal burning - open parkland model does, and does not, apply. Alternative causes for open formations will be developed.

The geomorphological consequences of the application of these concepts to inappropriate circumstances is examined, again using examples from south-eastern Australia. Evidence for post-occupation slope destabilisation is widespread. In many cases, the characteristics of slopes are such that present and previous geomorphic systems behave quite differently. It is concluded that landscapes need to be managed according to present circumstances, and according to geomorphic principles, rather than unrefined hypotheses.

Examination of environments to which the Aboriginal burning - open parkland model did apply suggests that the land management practices of the traditional owners had a lower impact on geomorphic processes and were more sophisticated than some of the literature suggests.

MORPHOLOGY OF THE GURRA GURRA CRESCENTIC DUNES, STRZELECKI DESERT, SOUTH AUSTRALIA

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Introduction: The variable morphologic character of the Gurra Gurra crescentic dune-field is a response to seasonal wind patterns that are locally enhanced by the shape, size and inclination of a dune-form's slopes. Field observations of dune advance, slipface orientation, the position of lee projections and depositional aprons, the streamlining and fluting of meso-yardangs and nebkha, obstacle induced erosional moats, as well as ripple pattern form, orientation and overprinting show strong relationships with both regional and intra-dunefield wind directions. From these associations an understanding is procured of the morpho-dynamic mechanisms involved in the equilibration and quasi-equilibration of dune shape.

Morphology: The lee to stoss convex-to-concavo-linear longitudinal form of winter is developed in dominant northerly winds. A leeward apron inclined between 2° - 7° extends some 2 metres from a gentle convex slipface. The slipface ascends from a maximum 28° at the lower lee, gradually changing to < 10° upon the upper lee-brink position. The crestal zone is sub-horizontal with the lee at a median inclination of 17°. A separated crest-brink forms a relatively wide zone with minor dune lowering. The crest acutely transcends windward into a rear slipface inclined at 26°. The stoss slipface is ≤ 1m high and demonstrates 'bottle-neck' patterns of sand avalanche with crestline notch affects. The windward gradient has a median slope of 8° gently rising from the sub-horizontal intradune floor and does not exceed 15° inclination. The mean height-to-length ratio is 1:10 and characterises the *non-equilibrated crescentic form* of dune reversal and windward extension.

Summer shape contrasts with the morphology of the winter dunes. A high intensity, long duration southerly wind sculptures and advances the summer dunes, where both saltation and significant suspension are active. The leeward sand apron is absent, while the slipface is at the angle of repose (32°±1°) from crest to intradune. Avalanche is characteristic of the slipface. A sharp intersection of the lee and stoss slopes forms a coincident crest-brink line, which defines a mean height-to-length ratio of 1:8. The stoss is linear with a gradient ≤ 14°, with zones of ripple induced undulation and gradient variation that characterise a median slope grade of 8°. The absence of the rear (stoss) slipface is also characteristic of the summer form and demonstrates *morphological and dynamic equilibrium.*

The autumnal dunes reflect the morphologic character of the summer dunes. In early-to-mid-autumn the winds are light and rarely reach saltation velocities. The slipface is at the maximum angle (32°±1°), with the maintenance of crest-brink coincidence. However, some dunes show the development of a nascent stoss slipface inclined at 26°. The ratio of height-to-length does not significantly alter from that of summer (H:L ~ 1:9), nevertheless, minor changes in the upper micro-morphologic configuration of the dunes, is indicative of the cyclic response of an imposing change in the seasonal wind direction as time advances towards the winter months, and a prevalent reversed flow regime.

In late spring, the dunes show characteristics of both summer and winter morphology. Albeit, considerable morphologic differences are expressed that signify spring to be an intermediate *quasi-equilibrated aeolian regime* between the southerly wind directions of summer, and northerlies of winter. Not unlike winter, an apron of lee side deposition is prevalent for those dunes whose gradients are not at the angle of repose and suggests either creep of the basal sands on the lower lee flank and/or avalanche of sands from the migrating crest. Although the leeward slope for some dunes is 32°±1°, many more gradients are between 24° - 28° (median = 22°), with the upper lee slope becoming convex in profile as the crest migrates northward under reversing winds. Overall, crest-brink separation is prevalent, but not as differentiated as with the winter dunes. Rather than a broad flat crest, the crestline rises to an apex which mimics the antecedent summer shape. Mean dune height-to-length ratios portray a slight decrease in height relative to length, with H:L ~1:11.4. The development of the rear slipface inclined at 26° and being ≤ 1m in height, is a feature that mirrors the form of early winter. The inclination of the stoss gradient is characteristic of all other seasons with a low median value of 6°. Also significant is the presence of a less well developed but prominent second rear slipface on the eastern flanks of the dunes, orthogonal to the first and dipping at an angle of ~26°. This feature infers a response to an oblique westerly air flow, that is also shown in the elongation of the eastern horns.

The dominance of one major wind direction of intensity strong enough to produce crescentic dunes, is a controlling factor in maintaining dune shape, although during most of the year, form is influenced by other less intense variable wind directions with greatest change occurring upon the crest-brink due to shear velocities that are enhanced by upslope wind speed amplification.

WIND EROSION RATES IN THE CHANNEL COUNTRY OF WESTERN QUEENSLAND

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Soil erosion by wind is an important agent of land degradation in inland Australia and although there has been considerable progress made in quantifying wind erosion rates on cultivated land (summary in McTainsh and Leys 1993), few quantitative data are available on broadscale wind erosion rates of the extensive semi-arid and arid lands of inland Australia.

A commonly used method describes broadscale wind erosion rates from meteorological records of dust event frequency (Middleton, 1984, Mctainsh et. al. 1990) and recent studies by Raupach et. al. (1994) and Knight et. al. (1995) estimate the dust loads in major dust storms. These studies do not, however, measure wind erosion in the terms which are most meaningful to geomorphologists, soil conservationists and land holders; soil erosion rates in mass of soil loss per unit area of land (t/ha), nor are they able to discrimate wind erosion rates on different land types.

The present study examines wind erosion rates on different land types at Diamantina National Park, in the Channel Country of Western Queensland, an area of high dust storm occurrence (McTainsh et. al. 1990). Data were collected on wind-eroded and deposited sediments, plus wind and other meterological conditions using a network of maxi-towers (10m high) and mini-towers (2m high) set up on different land types during 1994 and 1995. Wind erosion rates are presented on an event basis, and the relative importance of different event types are examined, as well as on a monthly basis, for the different land types. First estimates are provided of the relative erodibility of three major arid land types: dunefields, chanell alluvium and downs.

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HIGH RESOLUTION AEOLIAN SAND TRANSPORT MEASUREMENT IN NATURAL CONDITIONS

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Sand dunes front many coastlines and are recognised as important and fragile ecological and geomorphological features. Dunes are widely utilised for agriculture, recreation, nature conservation and a number of other uses. In spite of their wide distribution and high degree of utilisation however, the morphodynamic processes by which sediment is transferred to and from the dune, beach and nearshore zones are little understood (Short and Hesp, 1982; Sherman and Bauer, 1993). Better understanding of the physics of the beach and dune system will produce more focused coastal zone management with an enhanced database on which to base decisions. Detrimental effects from contemporary climate change (secular sea-level rise and increased storminess), are predicted to cause breaching and inland flooding of many low lying systems (Carter, 1988; Carter *et al.*, 1990). Thus contemporary, more detailed investigations are warranted of future morphological change in sand dunes including the mechanics of beach and dune processes that supply sediment to dune systems. Identification of potentially vulnerable dunes and recognition of failures in the sediment supply to dunes relies largely on sediment budget predictions derived from semi-empirical transport models. These models, developed largely in wind tunnels, have proved to be unreliable when applied to natural field conditions (e.g. Anderson, 1991; Jackson, 1993).

High resolution field measurement of aeolian transport under natural environmental constraints were conducted using state-of-the-art technology developed by the author (Jackson, 1996). A new aeolian sediment trap is used to give up to 1 Hz measurement frequency. The trap adopts a circular, horizontal trap design with a load cell connection to give continuous, omni-directional and unobtrusive trap measurement of sediment flux. Simultaneous wind velocity recording is carried out using an anemometer. Initial results using a direct comparison of wind velocity data, sampled at an equivalent frequency, have given a first order relationship between sediment flux and velocity. The trap enables simultaneous monitoring of wind velocity and sediment flux at sufficiently short sampling frequencies to enable investigation of sediment transport dynamics under a variety of field conditions. Results from these investigations suggest a first order relationship between wind velocity and aeolian sediment flux with a quadratic functional form. This quadratic form is maintained in all conditions with only its coefficients varying with local environmental constraints (e.g. fetch distance, sediment size, moisture etc.).

This study provides detailed examination of micro-scale aeolian sediment transport in natural conditions and demonstrates the use of a high resolution measurement system. Results from this and ongoing work forms a significant step in helping to better understand aeolian processes and ultimately an enhanced prediction of sediment budgets for specific sites.

EROSION, VEGETATION AND LANDFORM DEVELOPMENT ON RECLAIMED AREAS OF OPEN-CUT COAL MINES IN QUEENSLAND.

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The operation of open-cut coal mines in Queensland involves the excavation of the sedimentary materials overlying the coal seam. Exposure of the seam with draglines results in the construction of large stockpiles of highly disturbed overburden material known as "spoil". Reshaping of the spoil to allow erosion control involves considerable earthworks and hence cost, and optimal landform design for long term stability is not yet known. The range of spoil materials is large and the nature of the disturbed material is often associated with poor infiltration characteristics and considerable hostility towards the establishment and maintenance of vegetation cover.

Best practice planning strategies for spoil reclamation, erosion mitigation and revegetation for long term sustainable ecosystem development after open-cut coal mining in Queensland, are not yet known. The monitoring of outcomes of reclamation strategies through a field survey of reclaimed areas of a range of ages can provide insight into reclamation strategies optimal over the long-term.

The field survey includes topographical mapping; determination of the topsoil and overburden media physical and chemical characteristics; vegetation survey and its assessment according to ability for erosion mitigation; and survey of evidence of erosion including topsoil loss, stone cover, rill and gully development and their spatial distribution. Survey of sites of different ages and of the same site over a period of years also allows the monitoring of landform development.

Background information regarding the site investigated includes the site's age; reclamation strategy employed; rainfall totals and event characteristics; and vegetative cover performance over time (where mine site records are available).

The methodology and outcomes of the ongoing field study into erosion of reclaimed and revegetated areas on open-cut coal mine sites is introduced. An investigation of the mechanisms involved in the behaviour of the media is presented. The development of a database of erosion and the associated physical and vegetative cover characteristics and their influence on long term erosional stability is discussed.

The research is part of the project "Post-mining Landscape Parameters for Erosion and Water Quality Control". The general aim of the parent project is to determine for reclaimed areas of open-cut coal mines, the critical topographic parameters (degree and length of slope) in combination with vegetative or contact cover required to ensure environmentally acceptable erosion and water quality control, and to allow scientific and economic design of the post-mining landscape.

DETERMINATION OF THE CONTRIBUTION OF RILL AND INTERILL PROCESSES TO THE EROSION OF RECLAIMED OPEN-CUT COAL MINING LANDSCAPES

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The use of draglines for the removal of overburden during mining of open-cut coal seams in Central Queensland mines results in the establishment of a steep sided landform. Without landform reclamation works, high intensity summer rainfall, combined with minimal vegetation cover, can lead to significant erosion from these high relief landscapes. Reclamation costs, however, can be as high as $25,000 ha^{-1}. Earthworks associated with the lowering of the steep sided overburden slopes contribute the majority of this cost, and small changes in the degree and length of slope of the final landform can dramatically affect the cost and success of the rehabilitation program. An understanding of the erosion processes at work in this environment will allow the development of appropriate planning and cost-effective landform design.

Laboratory research is investigating rill and interill erosion on soils and overburdens found within the post-mining landscape. The research then aims to relate the physical and chemical characteristics of the media to the type and extent of erosion under rainfall. Experimental results are used in the determination of erodibility parameters for a range of erosion models. A total of 34 soils and overburdens were collected by back-hoe from 15 open-cut coal mines in Central Queensland and shipped in 200 litre drums to the Erosion Processes Laboratory at The University of Queensland. Three replicates of the following measurements were taken for each media:

- interill erodibility estimated using a tilting flume (plots 3 m long X 0.8 m wide) and rainfall simulation equipment. 100 mm hr^{-1} rainfall was applied to plots at 5, 10, 15, 20 and 30% slopes. Measurements included, runoff rates, sediment concentration, electrical conductivity (EC) and pH of runoff, and particle size analysis of eroded sediment.
- rill erodibility estimated using a 3 m flume (0.8 m wide & 0.15 m deep) and the metered addition of overland flow to the top of a 20% slope
- media characterisation; bulk density, pH, EC, texture, dispersion ratios, organic matter content, cation exchange capacity, exchangeable sodium percentage

Interill erodibility was calculated using the Modified Universal Soil Loss Equation (MUSLE). Critical thresholds for rill initiation have been determined following procedures adopted by the United States Department of Agriculture (USDA) Water Erosion Prediction Project (WEPP). Laboratory rainfall simulation measurements can be calibrated against data collected in the field under natural and simulated rainfall.

The work is part of the project "Postmining Landscape Parameters for Erosion and Water Quality Control". The project aims to determine, for reclaimed areas of open-cut coal mines, the critical topographic parameters in combination with vegetative and contact cover, required to ensure environmentally acceptable erosion and water quality control.

DEPRESSIONAL SALT ACCUMULATIONS ON REHABILITATED OPEN-CUT COAL LANDSCAPES IN THE BOWEN BASIN QUEENSLAND

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The landscapes under investigation are the result of the dragline operation for the removal of overburden above the coal seam. After reshaping of the steep spoil piles left in the wake of the pit, the landscape is still elevated and hilly. In many cases, the spoil material at and near the surface is very saline.

In the interests of successful vegetation reestablishment, often the prerequisite for slope stability and long term achievement of the intended postmining land use, it is hoped that leaching profiles are soon established. This is more often the case than not. Typical cores on the slopes show saturated soil solution extract electrical conductivities increasing with depth to about 0.5m, this implying movement of solute away from the root zone. But the question is posed: just how much does runoff salt release contribute to this developing deficit in the root zone. If there is significant surface runoff transport of the solute then lower areas are threatened (as well as offsite contamination becoming a concern). Indeed, salt crustations have been observed in low lying areas on some sites.

In this study is one dimensional finite element modelling of the rootzone is carried out. The basic conservation equations of water and a solute species is solved in a continuum approximation together with a suitable surface boundary condition. Laboratory experimentation, including rainfall-drying cycle simulation with a 3m x 0.8m inclined bed, for the given material (ie. site), will enable verification and calibration of the model. Then, within certain assumptions, long term predictions can be made with respect to the total solute expected to be released from newly created slopes. The development of depressional salt accumulations can, therefore, be predicted in turn for particular topographies.

The above study is part of the project "Postmining Landscape Parameters for Erosion and Water Quality Control", the aim of which is to determine the critical topographic parameters (degree and length of slope), in combination with vegative or contact cover, required to ensure environmentally acceptable erosion and water quality control, and to allow scientific and economic design of the postmining landscape.

THE EFFECT OF VEGETATION AND SURFACE RIPPING ON EROSION AND HYDROLOGY OF THE RANGER URANIUM MINE, WASTE ROCK DUMP.

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Rainfall, runoff, suspended sediment and bedload sediment data from large scale erosion plots ($600m^2$) under natural rainfall events were obtained from three sites (Cap, Soil, Fire) on the Ranger Uranium Mine waste rock dump (WRD) during the 1994/95 wet season.

The cap site (2.8% slope) was not surface ripped and had negligible vegetation. The soil site (1.2% slope) was surface ripped, top-soiled and revegetated and the fire site (2.3%) was vegetated with well established trees (*Eucalyptus* spp. and *Acacia* spp.) that were approximately 10 years old and surface ripped.

The quantity of bedload sediment eroded from the soil and fire sites decreased during the monitoring period, however the same trend was not observed on the cap site. Relationships between the total bedload loss and total sediment loss have been developed for the sites.

Reduction in bed load loss on the fire and soil sites is probably due to a combination of the significant increase in vegetation coverage during the wet season and denudation of erodible material. Early wet season rains may have washed off sediment that might have been detached and made available during the preceding dry season and increasing vegetation during the wet season acted as a protective agent for the sediment reducing the supply of available material.

For corresponding storms at each site the bedload erosion is highest from the capsite which has no vegetation and is not surface ripped. The bedload erosion is higher for the soilsite (which has grasses and low shrubs) than for the firesite (which has grasses and low shrubs but also tall trees and a thick cover of leaf litter).

The main change occurring between the sites during the monitoring period is vegetation cover on the soil and fire sites. This indicates that increasing vegetation coverage is the major factor controlling the temporal reduction in sediment loss.

FRIDAY 4TH OCTOBER

Magnetic Sourcing of Bedload in Wolumla Ck Catchment, South Coast, NSW

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Coarse bedload may be difficult to source or trace because of a lack of distinctive chemical or physical properties and the need to sample large quantities for reliability. Wolumla Creek is a tributary of the Bega River in southern coastal NSW which carries a dominantly sandy bed load reflecting its mostly granitic catchment. Presently the creek appears to be contributing a large proportion of the sand which has this century changed the character of the river from a relatively deep stream to an ephemeral wide, shallow sand-bedded channel. Within the Wolumla catchment there are several likely sources of sediment, mostly areas of gullying of Holocene valley floor sediments. This project aimed to source the sediments in the trunk stream to individual sub-catchments and quantify relative contributions using mineral magnetic characterization of the bed load. The magnetic 'signature' of a sediment is determined by its magnetic mineralogy (often related to parent lithology) and magnetic grain size. Several lithologies of bedrock are present in the catchment which were expected to provide contrasting signatures.

From six confluences, relative stream contributions could be quantified at only three. At other confluences problems arose with (1) scatter of results, probably due to the relatively large grain size and inherent problems of irreproducible sampling (2) similarity of magnetic signatures (3) weak magnetic strength, probably due to large magnetic grain size and low concentrations (4) lack of conformity of data to the sediment mixing model, particularly for the coarsest fraction.

In addition, we became aware of a fundamental weakness of the approach: while in some instances able to determine fractional contributions from tributaries at a confluence, there was no way to measure quantitatively the transfer of sediment between confluences. Therefore sediment stored in mid-catchment sinks or derived from banks or bed between confluences was unaccounted for. The sediment transfer model required 100% efficient sediment transfer of sediment derived from discrete locations at the head of each creek.

The magnetic technique is therefore unlikely to be of use in sediment sourcing studies, in bedload streams or in areas without very marked lithological contrasts. It is most applicable to suspended load systems and specifically to 'reservoir' sites where fractional contributions from separate catchments debouching directly into the sink may be distinguished.

GULLY DEVELOPMENT IN THE KAPUNDA FOREST, SOUTHEAST NSW, AUSTRALIA

MAJID SOUFI[1] AND IAN P. PROSSER[2]

After four decades of pine plantation in the southeast of NSW, a catastrophic gully erosion occurred in the Kapunda forest in the south of Bombala in 1988. Anecdotal and historical evidence show that intense rainfall, the disturbance of susceptible soil by ploughing and the poor construction of log rows were important factors in gully initiation.

The results of present research show that the rate of gully erosion follows a negative exponential trend. Sediment yield varies between 460 and 1630 m3/km2/yr in different gullies. The linear extension of gullies varies between 128,6 and 2 meter per year. The maximum rate of sediment yield and linear extension is higher than previously reported values in the world.

Detailed measurements of the erosion processes of gully development show that block failure, undercutting and other processes such as spalling, creeping and cracking had caused 30, 28 and 42 percent of the gully erosion respectively. It was found that block failure was more dominant at the head of the gully while undercutting was dominant at the banks.

The measurement of erosion and hydrologic processes shows that most of the amount of head erosion is caused by seepage. As indicated by the results, although seepage was the most important hydrologic process at the head of channel, surface runoff also caused erosion.

Overall, results indicates seepage, surface runoff and channel flow were necessary to maintain gully development.

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TRIALLING LOW COST OPTIONS FOR RIVER RESTORATION: NAMBUCCA RIVER, NSW.

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Community concern over the degradation of the Nambucca river and its tributaries has lead to the development of a joint river restoration program between the NSW Department of Land and Water Conservation (DLWC) and local Landcare groups. A number of low cost engineering works have been trialled at various sites throughout the catchment. This presentation will discuss the success of the program to date at two sites on the Nambucca River, mid north coast, NSW.

The Nambucca catchment was originally well vegetated with tall open forest on the ridges and upper slopes, rainforest along drainage lines and protected slopes, and riverine rainforest covering the alluvial flats. The river has suffered serious degradation since the late 1940's. Contributing towards this degradation has been the over clearing of vegetation from the floodplain and river banks, large sections of uncontrolled stock access on river banks, removal of natural bed controls, uncontrolled sand and gravel extraction and periods of major flooding. This has led to a river in which the majority of reaches have lost their natural pool/riffle sequence and have experienced bed lowering of up to 1.5 m with associated channel widening. Based on an historical channel change study using aerial photos it was calculated that the width had increased from 10-20 m predegredation to 40-60 m post degradation. The processes of bank erosion, floodplain stripping and sedimentation have lead to a loss of valuable river flats, pumping holes and a general decline in river health.

The restoration approach that was adopted, was to implement low cost, environmentally sensitive engineering works that would assist in stabilising the river bed, re-establish the pool/riffle sequence and also narrow down the width of the river channel. A fencing and revegetation program was also employed.

At a site involving the Argents Hill Landcare group, a series of V-notch log sills, log groynes and various revegetation techniques were trialled. After a series of floods of less than bankfull discharge (~1 in 5 year) the structures met with varying degrees of success, while others failed outright. To determine the causes of failure and develop a new restoration plan the site was reassessed using a multi-disciplinary team approach. This resulted in a new trial being carried out using new and modified works. These works included adjustments of the original sill design, as well as brush groynes interplanted with native tubestock, vertical timber groynes, and a series of direct seeding trials on the floodplain aimed at increasing roughness and controlling floodplain stripping. The whole site has been fenced from stock and alternative water points provided.

The North Arm Landcare group have installed a series of brush groynes and are trialling a direct seeding technique using native riparian species between each groyne in an attempt to realign the river channel away from an eroding outside bend.

The DLWC's RiverCare Program is providing various community groups with funding support to develop and trial a variety of low cost river restoration techniques. The above works are only a sample of innovative low cost river erosion control and revegetation methods that are being installed throughout the state.

MANAGING ACCELERATED CHANNEL CHANGE: TAYLORS CREEK NSW

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Taylors Creek is an example of the complexity of stream management when accelerated channel change has a significant impact on farm productivity. It shows that small streams can be just as complex as large river systems.

Taylors Creek is a small (2700ha) tributary of the Tooma River in the upper River Murray valley in New South Wales. Prior to 1960, the landholders of the area state that the creek posed no real management problems. It flowed down an incised channel to the floodplain of the Tooma River where it drained into a wetland area. Since that time, however, the creek has undergone rapid changes. The upper reach has experienced bed degradation of up to two metres. This has triggered large scale bank slumping, resulting in the loss of valuable upland pasture. Immediately downstream of the degrading reach, the creek has aggraded by up to one metre. This has resulted in extensive waterlogging and sand deposition on the Tooma River floodplain which is used for intensive dairy cattle grazing.

Surveys, observations of channel change indicators and land owner interviews have revealed the causes of the changes.

The bed degradation was most likely initiated by the channelising and draining of the wetland area, coupled with the removal of riparian vegetation such as blackberry. This increased the velocity of flow in the lower reaches as a result of the reduced backwater effect. These higher flow velocities scoured out the sandy bed material and produced a low headcut. This quickly progressed upstream, getting higher as it went. It was finally stopped by a bedrock outcrop, 1.2 km upstream from the start of the drainage channel.

The creek now appears to have reached a stable slope. However, the past degradation has released a large volume of sand. This was transported downstream and filled the low-slope wetland drainage channel. It then spilled out onto the floodplain. As a result of this, the landholders on this downstream section are experiencing significant pasture productivity losses, disease risks, destruction of fencing and reduced paddock access. The landowners have spent $12,000 a year, on average, to dredge the creek and restore a free-flowing channel.

Although the bed is now stable, the past degradation has triggered off massive bank slumping episodes which still occur frequently. This problem is further aggravated by the fact that the incised channel intercepts the watertable, allowing springs to discharge from the creek banks, saturating them and causing slumping. The sediment added to the creek by the bank slumping is becoming just as significant as that which was released through the bed lowering. Consequently, there is now a large volume of sand stored in the upstream section of the creek bed as bars. These will continue to supply sand to the lower reaches for many years.

To address these problems, a long-term management plan has been developed with the landholders to deal with the problems on the creek. The strategies include:

- rock fill bed controls built on the degraded reach to trap the sand before it reaches the floodplain, restore the pre-1960 bed level and provide slumping banks with support;
- fencing and intensive revegetation on banks to provide protection and reduce the amount of groundwater seeping through the banks;
- removing the willows from the bed of the Tooma River which have trapped sediment and raised the river bed, increasing the backwater effect on tributaries such as Taylors Creek.

In conclusion, the works (if funded) to control the sources of excess sediment, reduce the transport of sand bed material and increase the flow energy in the lower reaches should alleviate the effects of accelerated channel change on Taylors Creek.

FROM RESEARCH TO REALITY - RIVERCARE!

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One of the goals of applied research in fluvial geomorphology is to develop an understanding of river systems to enable management activities to be carried out. The Rivercare Program in NSW is an example of the "on-ground" management end of the process. This paper is intended to stimulate some thoughts and discussion on how community groups carrying out river management activities can develop better links with the results of research.

So, what is the Rivercare Program? It is an intiative of the NSW Government to get the community involved in and raise awareness of river management issues. It provides funding for river management plans and on-ground works, and also education and public awareness activites about river management. It has been running since 1993 and has become an extremely successful program with $3.2 million dollars allocated in 1995/96.

The participants in the Rivercare Program are community groups working in conjunction with the NSW Department of Land and Water Conservation, through the Total Catchment Management process, which enables other government organisations and also researchers to become involved. The word "community" incorporates many different sorts of groups and people. The Rivercare Program enables rural and urban dwellers, riparian landholders and people located elsewhere in the catchment, school groups, Landcare groups, Rivercare groups, local environment groups and even other government agencies, to become involved in looking after and repairing their local river or stream - ranging from the mighty Murray to the smallest coastal urban stream. The majority of activity takes place in the upper to middle catchments, due to a combination of population and erosion location. At present, there are ???? groups working on Rivercare projects around the state.

The question begs then, what are all these groups doing? The activities of community groups on rivers fall into three main categories:

1. revegetation, fencing and stock management along rivers and streams;
2. bed and bank erosion/sedimentation control works (usually accompanied by revegetation);
3. and nutrient control works (such as sediment traps, artificial wetlands and buffer strips).

Given that there are so many people "on the ground" carrying out river management activities, it would seem obvious that they know what they are doing - or do they? At present, planning and works are based on best management practices and a lot of trial and error. This is where it is imperative that information is shared, to ensure that all the hard work and money are not being wasted. To enable this to happen, there are 3 important links to be maintained (and improved if possible):

1. links with researchers (both academic and government) - community groups need up-to-date and easily understood information on both river processes and management strategies to overcome degradation;
2. links with government agencies to enable help them to develop and improve policy and legislation related to river management activities; and
3. links with other community groups, in other areas, states and even other countries, to share their knowledge of river processes and management techniques, and also to minimise the chance of making the same mistake twice!

Community based river management on a large scale is still in its infancy. With the co-operation of <u>everyone</u> involved in river management (researchers, managers and landholders), the work that is done can be based on the best knowledge of the time, and hopefully, a <u>real</u> difference can be made to our rivers and streams.

USE OF TRIAL RELEASES FOR THE PREDICTION OF THE BIOGEOMORPHIC IMPACTS OF INTERBASIN WATER TRANSFERS

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Sydney Water has supplemented the Sydney and Wollongong water supply systems by transferring water from the Shoalhaven River to either Warragamba or Nepean Dams in the Hawkesbury-Nepean River basin. The potential impacts of operational releases on the channel morphology and fish on a section of the Nepean transfer system were assessed by two trial releases in 1992. The first release extended from 18 to 22 March 1992, had a step-functional shape with a maximum discharge of 1674 ML/d, diverted 3484 ML of water and transported 120t of suspended sediment. The second release extended from 7 to 9 April 1992, had a step-functional shape with a maximum discharge of 590 ML/d, diverted 526 ML of water and transported 24 t of suspended sediment. Mean bank erosion rates during the first release were 38.5 ± 39.0 mm but were only 10.3 ± 20.6 mm during the second release. Time weighting of these mean erosion rates produce annual rates of 3.5 m/a and 1.9 m/a, respectively. The main erosion processes were entrainment and sloughing of sediment off the bank face. Bank sediments were dominantly muddy sands and clayey sands which are non-dispersible. When vegetated, these river banks do not erode. From gravel tracers, it was found that the largest gravel clast transported by the first release was 279 mm in diameter but that there was little size difference between transported and stationary clasts. The second release transported gravels up to 173 mm in diameter but the size range of stationary gravel clasts overlapped with that of the transported clasts. Threshold of motion calculations using an excess tractive force approach and a 20% chance of motion produce results which agree closely with the gravel tracer findings. Lichenometry was used to determine that gravel clasts smaller than 580 mm in diameter had been mobile since 1970. Clasts larger than 710 mm had not been mobile since at least 1970. To be certain that the bed will not be mobile during operational releases comparable to the March 1992 trial release, the bed would need to be protected by gravels between 290 and 480 mm in diameter, depending on the sedimentary environment. As this does not occur naturally, bed load transport is likely to be active during operational releases of about 1600 ML/d until the bed becomes much coarser.

Flathead Gudgeon (*Phylipnodon grandiceps*) were killed and/or injured by both releases. Specimens with cutaneous lesions, loss of epidermal tissue and damage to the caudal peduncle, fins and gills were found after each release. About 10 dead fish were also collected from beneath rocks as well as along the debris line of the peak release. Mobile clast impact or rolling of shelter clasts caused these injuries. One freshwater crayfish (*Euastacus* sp.) and one long-necked tortoise (*Chelodina longicollis*) were also killed by mobile gravels.

Trial releases are a valuable method for identifying potential problems with interbasin water transfers and their location. Although duration-dependent effects cannot be recognised by short trial releases, judgement based on personal experience may be reasonably accurate, as in many engineering practices.

PALAEOFLOOD DEPOSITS IN THE LACHLAN GORGE: IMPLICATIONS FOR TERRACE AND FLOODPLAIN FORMATION, AND THE FLOOD RECORD.

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The Lachlan River below Wyangala Dam, SE Australia, is flanked by two terraces: a higher 'red' (25 m above the channel bed), and a lower 'brown' terrace (15 m above the bed). The present active floodplain forms a low bench below the brown 'terrace'. Before 1990 a passing geomorphologist would have interpreted the brown terrace as a former floodplain, abandoned by incision. However, a large flood in 1990 down a newly constructed spillway from Wyangala Dam neatly scoured the top five to ten metres of the brown terrace revealing a quite different morphology to that expected. The scour revealed eight well-defined, convex-up, fining-upward, very-fine to fine sand units (D_{50} = 0.125 mm) of 1-2m thickness draped successively over each other, with the toe of each unit beginning close to the present bed level, which is cut to bed-rock (Fig. 1). The second oldest of the units returned a TL age of 20 ka BP. The most convincing stratigraphic and sedimentological interpretation is that each of these units in the exposure is the result of vertical accretion from a large flood.

The site provides evidence for deposition of a 'terrace' by vertical accretion (as proposed by Nanson (1986)). That is the depositional surface was not deposited by lateral migration of a channel at a higher elevation, and then abandoned by later incision. Instead, 15 m of sediment was evidently deposited by the river *at its present bed level* in about nine floods to produce a feature resembling 'slack-water terraces' described in the SW USA. The corollary of this argument is that the deposits have also survived for 20,000 years without being 'catastrophically stripped' (Nanson, 1986). This is surprising given that the site is in a steep, confined gorge, and that deposition of each flood unit progressively confines the channel, increasing shear stress.

The deposit also provides a flood stage record from the last glacial peak to the late Holocene. The youngest (stratigraphically highest) flood-unit returned a ^{14}C date of 2,500 years. A stream gauge located at the site (80 year record) shows that this flood was at least 5m higher than the largest recorded flood. The deposits may therefore also provide information on the frequency of floods over the last 20 ka.

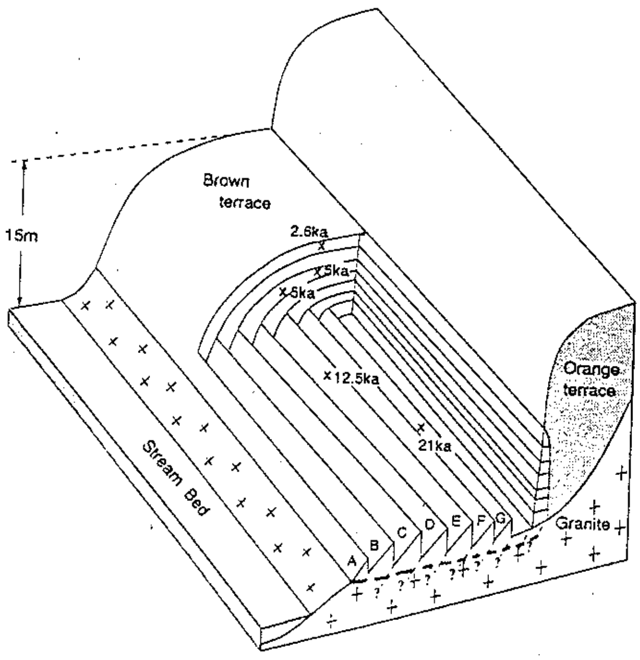

Figure 1: Schematic figure of the Wyangala erosion site (right bank). Note the eight convex-up on-lapping depositional units in the Brown terrace. Dates are marked eg. 2.6 ka.

Nanson, G. C. (1986). Episodes of vertical accretion and catastrophic stripping: A model of disequilibrium flood-plain development. *Geological Society of America Bulletin, 97*, 1467-1475.

The Geomorphic Effects and Chronology of Extreme Flood Events in Central Australia.

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The MacDonnell Ranges in central Australia lie on the fringe of the north Australian Monsoon. Geomorphic field evidence and enhanced satellite imagery of the Todd River catchment indicate the occurrence of extreme flood flows. These events were at least an order of magnitude greater than the largest flood on record.

The course of several large-scale (2-4 km wide), braided flood channels can be traced from the MacDonnell Ranges to the northern Simpson desert. These flows eroded aeolian dunes, entrenched older alluvium and caused channel avulsion. Large bodies of gravelly sands were laid down in longitudinal bars (2 km long) and extensive splays. A phase of aeolian dune accretion followed these flood events.

The age of flood sediments has been determined using radiocarbon and luminescence dating techniques. Results indicate that high magnitude floods occurred during the Pleistocene and Holocene. These results will be discussed in the light of recent suggestions of an increase in climatic variability during the late Holocene in tropical and extra-tropical regions (Baker, 1995).

Baker, V.R. (1995), 'Global Palaeoflood Hydrology of Tropical Rivers'. Abstract from the International Association of Geomorphologists Regional Conference, Singapore.

THE BUCHAN CAVES GRAVELS: IMPLICATIONS FOR PAST DEPOSITIONAL ENVIRONMENTS

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A systematic study of the gravel deposits of the Buchan Caves Tourist System shows that the gravels were predominantly derived from local Snowy River Volcanics of the Fairy Creek Catchment augmented by allochthonous fine silty clays. These gravel assemblages were deposited after a major collapse in Princess Royal Chamber (Royal Cave), blocked the system thus causing thick sequences to be deposited (Webb *et al*, 1991). Analysis of the physical size, shape and lithology of the clastic sediments and their relevant levels indicates that present intermittent high flow conditions do not adequately explain the extensive depositional sequences seen today.

By comparing the flow regimes of the coarse clastic sediments and that of wall scallops, two different events were described. The scallop formations represented high, slow flowing conditions whereas the gravel assemblages which reach the roof in some areas of the cave system indicate high, fast flows. The implications of this difference is informative on palaeoclimates and landscape evolution in the Buchan Region.

The cave gravels have the potential to explore and understand the palaeoflows of underground streams of the Buchan area and by analogy the past surface flows. Hence, the cave gravels are important in understanding the geomorphological history of the Buchan area.

The morphology and genesis of drainage runnels on the Sydney Basin quartz sandstones

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Small channels formed by aqueous dissolution as water flows across a rock surface are known by many names (*karren*, *lapiés*, gutters, rills or runnels). Whilst their occurrence on carbonate rocks has been closely studied, far less attention has been given to their occurrence on quartzite or sandstone. Nonetheless, whilst they have not previously been described from this area, runnel forms are very common on most quartz sandstones within the Sydney Basin, and a range of types have been identified.

Detailed field survey shows that the general distribution of runnels across the Sydney Basin is not uniform, nor do they necessarily conform to the generally accepted morphometric typology of genetically similar carbonate runnels. Microscopic analysis of the host sandstones showes intense solutional weathering to be an important element in the formation of sandstone runnels, just as it is with carbonates. However, other factors including source-water chemistry and especially general rock composition and strength are also important in the formation of Sydney Basin sandstone runnels.

CHANGING PLACES - RECENT COASTAL CHANGE ON BANKS PENINSULA

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Lake Forsyth, on the south side of Banks Peninsula, is cut off from the sea by Kaitorete barrier. Thirty kilometres long, and two wide at its eastern, downdrift end, this barrier has been considered by Kirk (1969) and by many local people to have changed little in the last 150 years. Recent work (Soons and Shulmeister) suggests that it may however have converted from spit to barrier only in relatively recent times (a few centuries at most). At the extreme downdrift end of the barrier, Lake Forsyth could be expected to have changed from marine inlet to brackish lake within historic or near historic time. A search of early maps and literature was therefore undertaken to test this hypothesis. It was supplemented with information from air photos and from local residents and tangata whenua.

Accounts by whalers and early settlers provide information for the first half of the 19th Century. Maps of varying degrees of precision are available from the mid-19th Century, and air photos from 1966. Together with recollections of various individuals, these provide a record of growth of the barrier at its extreme eastern end, associated with increasing separation of the lake from the sea. The image of an unchanging barrier thus requires modification to bring it into line with the known processes of erosion and transport of sediment along the coast of the Canterbury Bight.

LAGOONAL SEDIMENTATION ON LORD HOWE ISLAND

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Lord Howe Island (33°30'S, 159°05'E), in the Tasman Sea, appears to mark the southern limit of coral reef growth in the Pacific. The island is composed of Miocene basalts with a cover of Late Quaternary carbonate eolianites across the central axis of the island. Coral is abundant throughout the shallow water environments of the island but there is only one major reef which occurs on the western side. This reef forms a barrier 6 km long and around 100 m wide, with three deeper passages that allow wave energy to propagate into a shallow lagoon. The lagoon is shallow, generally less than 2 m deep. Three depressions, up to 6m deep, occur behind the reef crest. These occur in association with patch reefs in the lagoon and are the areas of most luxuriant coral growth.

Shallow continuous seismic profiling of the lagoon indicates that the depth to basalt varies up to 26m. An unconformity is indicated within the sediments. Vibrocoring within the lagoon did not reach this unconformity, however cores that penetrated close to the boundary encountered a basal coral gravel dating around 6.2ka. The majority of the cores recovered were dominated by 2.0 - 2.5m of fine carbonate mud. There is no modern analogue within the lagoon, with surface sediments being dominated by coarse sand and coral fragments. Fine grained material is restricted to Sylphs Hole and the southern end of Lagoon Beach where the density of benthic fauna is high. This unit was relatively homogeneous, and appears to have undergone rapid sedimentation with the majority of the mud being deposited between 6ka and 4ka. Onshore auger sections of the adjacent coastal plain indicate that the lagoon extended further landward with a consistent basal gravel of marine shells and coral at 2m below the high tide mark dating around 3.3ka.

The lagoon on Lord Howe Island therefore appears to have undergone sedimentation during the mid Holocene. This was characterised by low energy mud sedimentation overlying higher energy gravel sediments. The late Holocene was then characterised by gravel/sand deposition sourced from the reef crest. These coarser sediments are also the main constituent of the current coastal plain.

LATE QUATERNARY CARBONATE SEDIMENTATION ON LORD HOWE ISLAND

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Lord Howe Island, situated 700km east-northeast of Sydney, is a mid-ocean island composed of Miocene basalts and a discontinuous capping of Quaternary calcarenite. Units preserved within the calcarenite reflect a variety of depositional environments including reef flat, beach, dune and soil. Past studies of the calcarenite have supported a theory of deposition for the bulk of this sediment, the dune deposits, around the time of the Glacial Maximum, when the large wave cut platform surrounding the Island was exposed. However, our preliminary chronological results reveal these deposits to be far older and do not support this history.

Uranium-series disequilibrium (U/Th) dating has been undertaken on coral from a number of units. In a beach facies exposed at Neds Beach, on the Island's northeastern shore, coral clasts have been dated at 138ka. A gravel deposit below this unit contained coral fragments approximately 230ka. Thermoluminescence (TL) analysis of the quartz fraction of the beach sand returned ages of 116ka and 130ka. An aeolianite unit above this beach deposit was TL dated at 86ka. Similar aeolianite exposures south of Neds Beach at Middle Beach, and in a nearby quarry, were TL dated at 98ka and 91ka respectively. Amino acid racemisation dating of whole-rock and *Placostylus* (a terrestrial snail) samples from these units, and aeolianite at Signal Point, on the northwestern coast, support dune deposition around the Last Interglacial.

U/Th dating of speleothems deposited in aeolianite caves at North Bay, on the northern end of the Island, yield ages between 47-14ka. Stable isotopes of oxygen and carbon measured in a large stalactite suggest an abrupt switch in climatic conditions during the Glacial Maximum. The aeolianite is yet to be dated, but must predate the speleothems and have undergone subsequent solutional weathering during the Last Glacial.

A seismic reflection profile of the shelf on the western side of the Island indicates there is only minor amounts of sediment accumulating there, while lagoonal deposits, such as those found inside the fringing reef, represent a possible source of dune sediment on the island's western shore. However, measurements of aeolianite bedding structures indicate the majority of carbonate sand was derived from the eastern side of the island, suggesting a high energy beach rather than lagoonal origin for this sediment. As indicated by the dates, dune formation seems to be related to relatively high sea-levels, possibly slightly below Interglacial highstands, when beach sediments may have been reworked.

THE WAIPAOA: A GEOMORPHIC PERSPECTIVE FOR ASSESSING ENVIRONMENTAL CHANGE ON THE LARGE CATCHMENT SCALE

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Geomorphologists are asking - and are being asked - questions that require understanding of large systems, long time scales, and multiple disciplines. Basic questions concerning climatic control of landforms, interpretation of stratigraphic records, and tectonic geomorphology all require that interactions between hillslope and channel processes be understood over very large time and space scales, and that interactions between people, plants, and physical processes be explored. Questions of land-use planning, cumulative impact evaluation, and hazard mitigation in downstream cities require analysis on similar scales. Meanwhile, the shift towards explicitly relating research questions to market-led issues and problems controls the investment of research funds. As "users" confront problems involving broader time and space scales, it becomes imperative for researchers to address problems of the same scale.

An approach for evaluating process interactions at a large-catchment scale is being developed for an ongoing study of the 2204-km^2 Waipaoa River catchment, North Island, New Zealand. The overall goal of the study is the evaluation of cumulative environmental effects of land use change. A primary issue is the threat of flooding of Gisborne City and other towns and horticultural lands on the Gisborne Plains. Flood risk may be increasing due to aggradation of the Waipaoa River because of land-use changes that occurred 100 years ago, and those changes may also have led to increased flood risk due to hydrologic changes on hillslopes. To allocate funds for flood control, the Gisborne District Council needs basic information about the causes of increased flood risk, the likely trends of future changes in flood risk, the likely effectiveness of proposed mitigation measures, and the likely collateral impacts of those measures. A key issue raised by the Council is the relative benefits of raising stopbanks and of afforestation. In particular, they want to know the extent of afforestation required to reduce flood peak flows and thereby the capacity of the river to covey sediment. Ballpark estimates showed that the effect of afforestation on reducing bedload discharge is relatively minor unless a large portion of the catchment is afforested. However, these are management questions that need to be answered with certainty. Our research programme has been designed to do this by evaluating the influence of past, present, and potential future land-use activities on the production and transport of sediment and water in the Waipaoa catchment.

Research to address the problem follows several parallel tracks. To determine the influence of erosional changes, reconnaissance-level sediment budgets are being constructed for each of 16 land types in the catchment. Representative tributary catchments within each land type are selected for evaluation, and results from each are used to characterise sediment production and storage through the rest of that land type. Major sediment sources include shallow slips, gullies, and earthflows, and these are evaluated through a combination of aerial photo interpretation, field assessment, and results of previous erosion research in the area. Rates are defined as a function of land use and vegetation type. Hydrologic changes are assessed primarily by scaling up the results of past plot- and small-catchment-scale monitoring studies and by field observations of storm runoff from hillslopes under different vegetation covers and land uses.

Changes in sediment transport are being evaluated from changes in channel morphology measured on sequential aerial photographs and from channel cross sections monitored since 1947. Studies of bed material composition demonstrate the provenance of the accumulating sediment and allow correlation between sub-catchment sediment outputs and channel response. Sediment transport measurements allow evaluation of the influence of changing sediment input on the location and rate of past, present, and future aggradation. Stratigraphic and palynologic studies of Holocene floodplain sediments allow the Waipaoa River's response to long-term changes in climate, vegetation, and land use to be understood, and these patterns aid interpretation of likely future changes in the river's response.

The multiple aspects of the Waipaoa study are united and organized by their shared focus on the overall problem: how does a large river respond to changing conditions on the hillslopes that feed it? Different tributary catchments have responded in very different ways, and comparison between sediment budgets, water budgets, and sedimentation history for the tributaries will allow evaluation of the factors that control a river's response to changing conditions, as well as provide the information needed to plan efficient flood control efforts.

EXPERIMENTAL TESTING OF A LANDFORM EVOLUTION MODEL

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SIBERIA is a physically based computer model for simulating the evolution of landscapes that links widely accepted hydrology and erosion models under the action of runoff and erosion over long time scales (Willgoose et. al,1991). SIBERIA is an important tool in the understanding of the interactions between geomorphology, hydrologic process and response. This is primarily because of its ability to explore the sensitivity of a system to changes in physical conditions, without many of the difficulties of identification and generalisation associated with field studies. One technique for testing and calibrating such a model is to compare SIBERIA to a small scale experimentally eroded landscape in which initial conditions and evolutionary controls are either known or controlled.

This research has required the development of a suitable model landscape using experimental geomorphological techniques and the extraction of a digital terrain map from the experimental surface using digital photogrammetry. Extensive pit removal of the experimental surface has been required because of errors resulting from the digital photogrammetry algorithms.

A calibration of SIBERIA has been performed using a simple planar (one-dimensional) catchment. The calibrated model was then compared to a more complex planar landscape with two-dimensional flows using the hypsometric curve and the area-slope relationship as the tool of comparison. A comparison of the hypsometric curve and the area-slope relationship validate SIBERIA for this type of catchment.

Current work has focussed on other geomorphological and hydrological statistics as tools of comparison such as the cumulative area diagram and the width function. A good agreement between a SIBERIA simulation and the experimental landscape is observed for the cumulative area diagram. A comparison of the simulated and experimental width function indicates that SIBERIA consistently predicts a shorter width function than observed so that flow distances are shorter. A number of explanations for this behaviour are currently being explored including one that suggests that data may itself be in error because of the pit filling algorithms required for drainage network extraction.

REFERENCE

Willgoose, G., Bras, R. L., and Rodriguez-Iturbe, I., 1991, Results from a new model of river basin evolution: *Earth Surface Processes and Landforms*, v. 16, p.237-254.

A SEQUENCE OF RAIN FOREST FIRES IN FERAL MOUNTAINS OF PAPUA NEW GUINEA

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A pit in andesite ash from Mount Lamington on a low col of the Owalama Range in Papua at 1350m is in mossy lower mountain rain forest with an annual rainfall of between 2000 and 2500 mm. Nearby a finely dissected ridge and v-valley landscape with 55° side slopes has a relief of 15 to 20m, the thickness of the ash cover. On average the ash was deposited at a rate of 17cm ka^{-1} and has rapid permeability. In detail there are several ash episodes with topsoils separating them and the topsoils formed at 25cm ka^{-1}.

Ozocerite and bitumen at the top of paleosols alternate with less altered organic matter in subsoils. These residual hydrocarbons were formed by forest fires at 5000, 8000 and 13000 years ago at the surface when leaf litter was abundant.

Self combustion is possible in severe droughts or they may have been lit by travelling natives, or lightning strikes. Many mineral grains are sintered and may not commence weathering for long periods. In the subsoils charred wood, not heated above 350°C, comes from the forest in the Mount Lamington crater.

Much earlier the ashes show a shortfall of weathering between 16,000 and 18,000 years equivalent to a temperature drop of 10°C similar to the New Guinea glacial. The climate over the last 10,000 years, however, has remained about constant. Large freshwater swamps also occasionally dry out and burn leaving tell tale burn patterns.

Oxidation of iron and organic matter run roughly in parallel as do silica to cation ratios and decay of cations. Ash composition is glass, plagioclase, hornblende and minor biotite with median diameters around 0.25mm, and good sorting. Clay minerals are allophane, minor vermiculite and rare imogolite. Bulk density of the ash varies from 1.1 to 0.8 tm^{-3} when fresh to 0.5tm^{-3} when very weathered.

If buried whole, in a window, this ash would be a good oil producer having well over the required carbon content, varying from 2 to 20 per cent with an average of 5 per cent.

POSTER PRESENTATIONS

T. Fanning, S. Holdaway & D. Witter

Eliminating the noise: A new application of geomorphology to open site spatial archaeology in Sturt National Park, NSW

I. Reinfelds

Erosion scars along braided rivers; evidence for high magnitude floods along the Waimakariri River, New Zealand

EROSION INDICATORS IN 190 K YEAR-OLD BASALTS

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A number of Cainozoic basaltic provinces occur in North Queensland, with ages ranging from the oldest (over 44 million years) to the youngest provinces, Atherton, McBride and Nulla in which the most recent volcanoes are from around 10 to 20 K years old.

Volcano and lava surface forms are well preserved from the youngest activity, in which the original lava surfaces are evident. In such localities perhaps up to a centimetre of glassy crust has been eroded, but locally this is also preserved.

Comparison with older lava flows areas indicates considerable differences, where these flows range up to 5 million years. Surface details have gone, and it can be concluded up to perhaps 10 metres or more have been removed by erosion. Outcrop is also contrasted, generally having deeper regolith, and the common occurrence of round to oval-shaped basalt kernel boulders on the surface.

Examination of flows older than the youngest flows (near Malanda -10K? in Atherton; Kinrara in McBride-c.20K?; Toomba-13K in Nulla) commonly reveals some pertinent details.

In the youngest flows, lava rises are very common. Such features came to be interpreted as formed by inflation of lava surface crust within only the last 6 years. Walker (1991, Bull Volc. 53, 546-58) and Hon et al (1994 Geol Soc Amer, Bull., 106, 351-70) provided the first detailed documentation of this commonplace phenomenon.

In these youngest lavas, inflation (up to 20 metres) causes the crusts to fracture producing "clefts", up to several metres across and in places over 6 metres deep. These clefts provide important information about the internal structure of the basalts.

Typically, deeper than 1 to 2 metres beneath the surface, lava segregations are evident in the young basalts. They occur as pipes, sills and "blobs" which are distinctive in being darker (more Ti) and more coarsely vesicular than the adjacent basalt. Their significance was first recognised by Smith (1967 Am J Sci, 265, 696-713). Anderson et al. (1984 J. Geol. 92, 55-72) accounted for their formation in terms of partial melt crystallisation and gas filter pressing.

Segregations of various kinds can commonly be observed in older lava flows, demonstrating that many metres of surface erosion has occurred.

The Undara Lava Flow, 190 K years (Griffin & McDougall, 1975, J. geol. Soc Aust, 22, 387-96), shows thin vein segregations in many surface outcrops, and less-common pipes in others. Their appearance in this relatively young flow shows that perhaps 1 to 2 metres erosion, as a minimum has taken place in that period.

This raises good questions about general rates of landform evolution, and what erosion processes are involved. Age determinations in the basalt provinces north of Hughenden indicated drainage incision rates averaging 20B (equals 4m in 200K). Slower general degradation appears to be occurring in Undara because lava rises are still prominent with typical morphology. Clefts are very difficult to recognise - probably being infilled by edge collapse. Thin stony regolith occurs, but soil flats between lava rises have thicker soils which may represent transported weathering products. With time, lava rises become obliterated and the characteristic, broad flat plains of older flow areas (millions of years) develop. These regional plains represent eroded landforms, with tens of metres of surface lowering. In ancient regions involving sporadic subaerial volcanism, similar eroded landforms probably develop. They call for careful scrutiny to confirm just how much of the volcanic record is preserved.