Geochemistry and provenance of sediments

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Sediment Sinks Sources & Drivers in the Normanby Basin

CAPE YORK WATER QUALITY

Reef Rescue Research & Development

Griffith UNIVERSITY

CARING FOR OUR COUNTRY

Key messages

- Sub-soil sources dominate the supply of sediment to the channel networks
- ~10% of the sediment in the bay comes from the upper catchment
- Erosion of the coastal plain is the dominate sources of terrestrial sediments in the bay

Two parts

- Dominant erosion process in the catchment
  - Surface vs subsoil soil erosion

- Geochemistry and provenance of sediments from Princess Charlotte Bay

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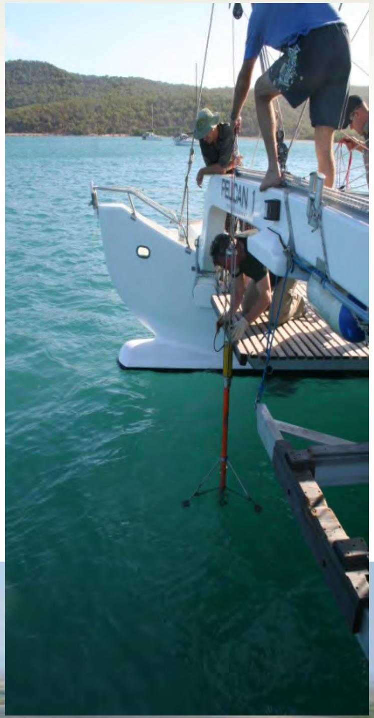
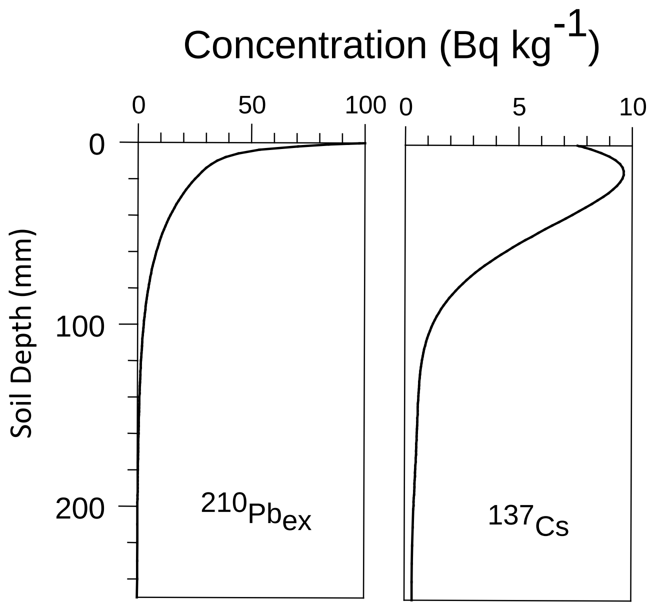


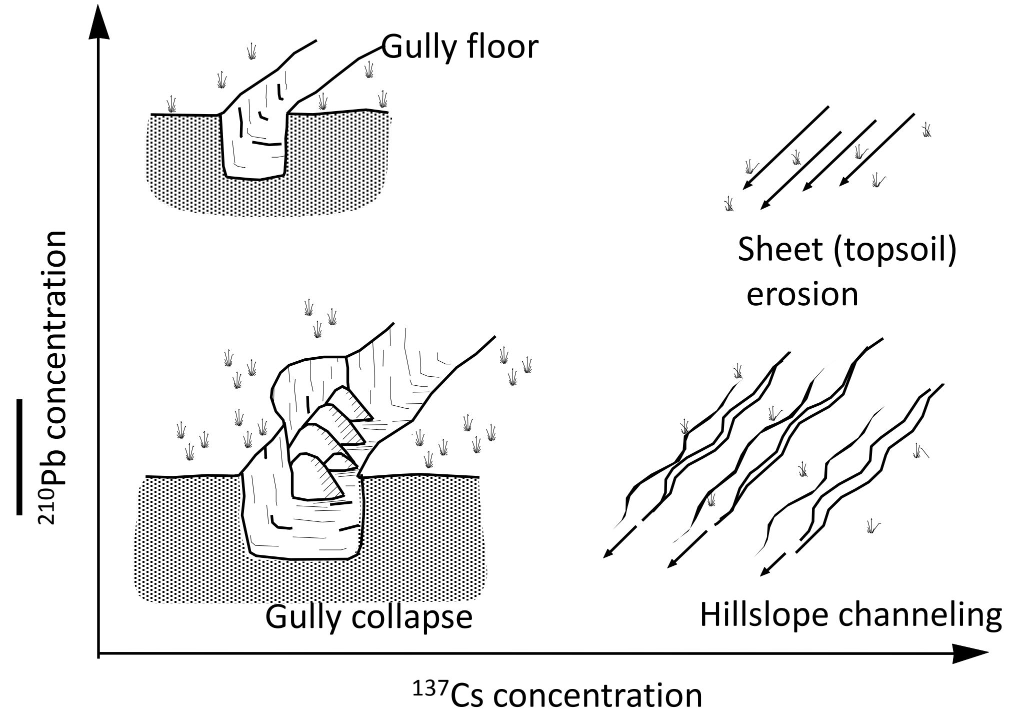
Dominant erosion process in the catchment

- Previous studies identified surface soil erosion as supplying around 90% of the sediment
  - Brodie, J., McKergow, L.A., Prosser, I.P., Furnas, M., Hughes, A.O., Hunter, H.(2003) Sources of sediment and nutrient exports to the Great Barrier Reef World Heritage Area. ACTFR Report 03/11. pp. 192
  - Prosser, I.P., Rustomji, P., Young, W.J., Moran, C.J. and Hughes, A.O., 2001. Constructing River Basin Sediment Budgets for the National Land and Water Resources Audit. CSIRO Land and Water, Technical Report 15/01

Dominant erosion process in the catchment

- Fallout radionuclides (Cs-137 and Pb-210) to test the hypothesis that surface soil erosion dominates the supply of fine (<10um) sediment in the river systems draining into Princess Charlotte Bay





Dominant erosion process in the catchment

Sample collection: surface runoff and sediment traps

N = 65

Dominant erosion process in the catchment

Sample collection: gullies and channels

N = 80

Dominant erosion process in the catchment

Sample collection: suspended sediments and drape

21 locations 2 wet seasons

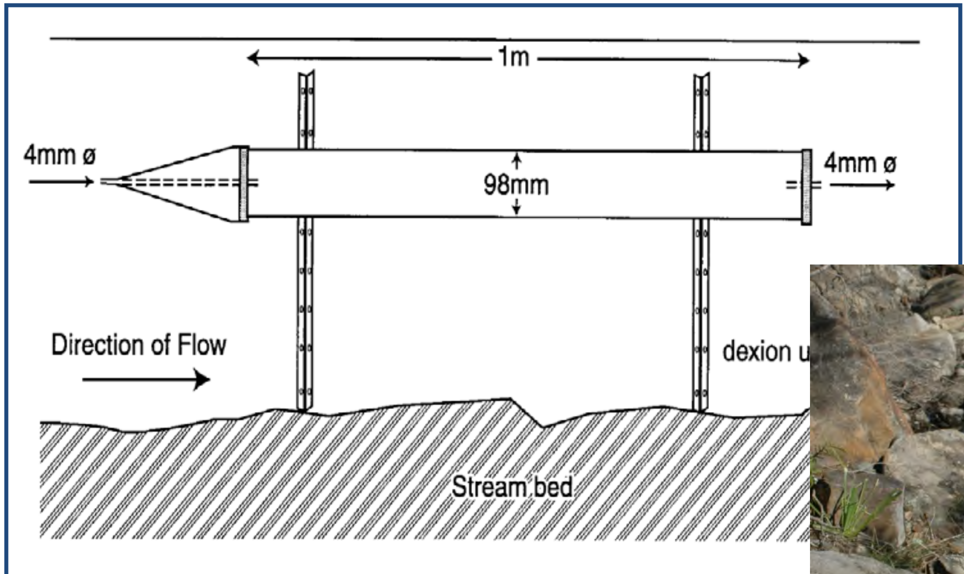


Figure 1. Cross-section of the suspended sediment sampler

Phillips, J.M., Russell, M.A., Walling, D.E., 2000. Time-integrated sampling of fluvial suspended sediment: a simple methodology for small catchments. Hydrological Processes, 14(14), 2589-2602.

Sample preparation for gamma spectrometry

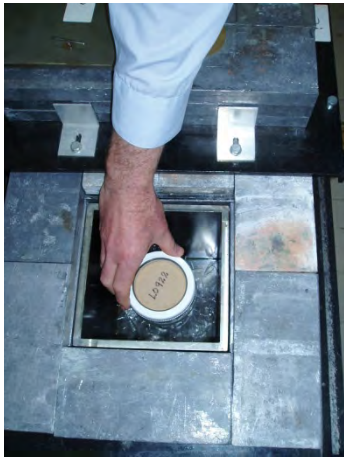
particle size separation

drying

grinding

Gamma spec

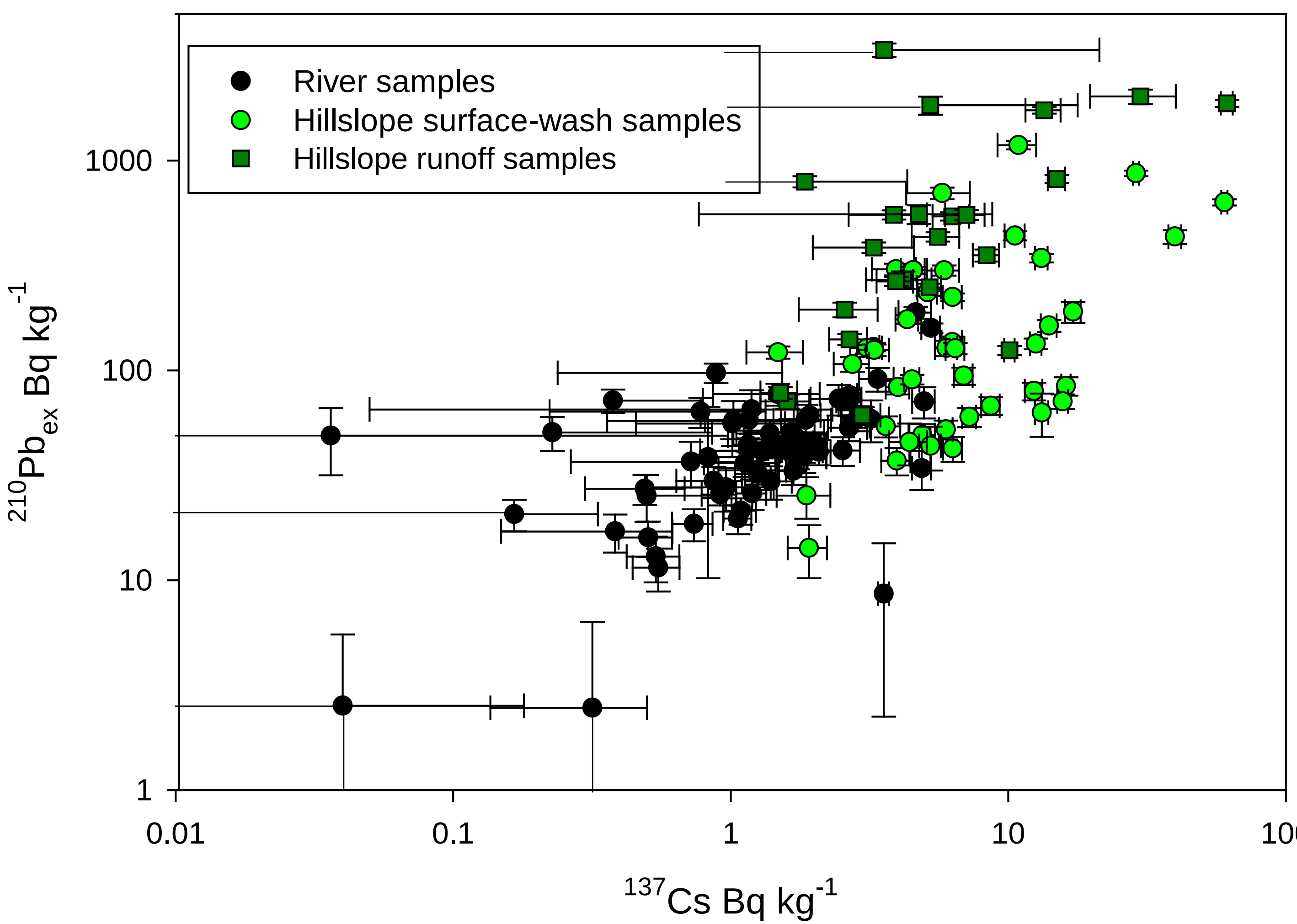
Formation into a disc



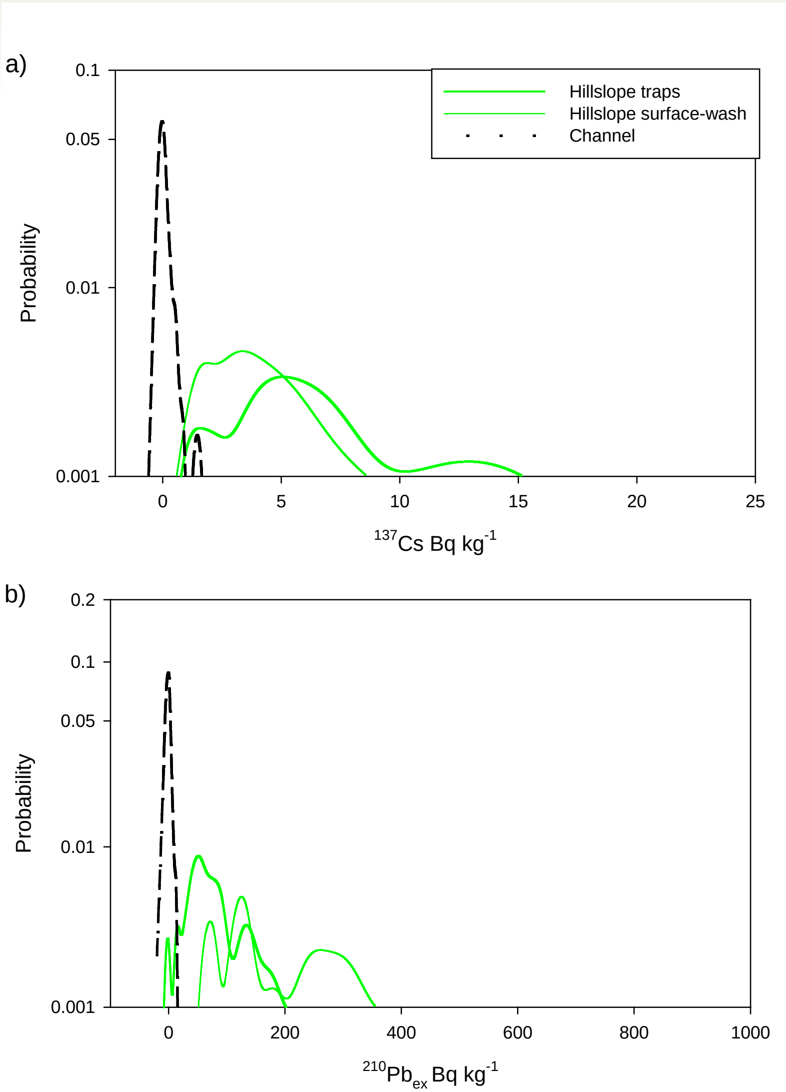
Counting by gamma spectrometry

Analysis of the samples was undertaken at the CSIRO radionuclide laboratory in Canberra, Australia.

Dominant erosion process in the catchment



Probability distribution modelling

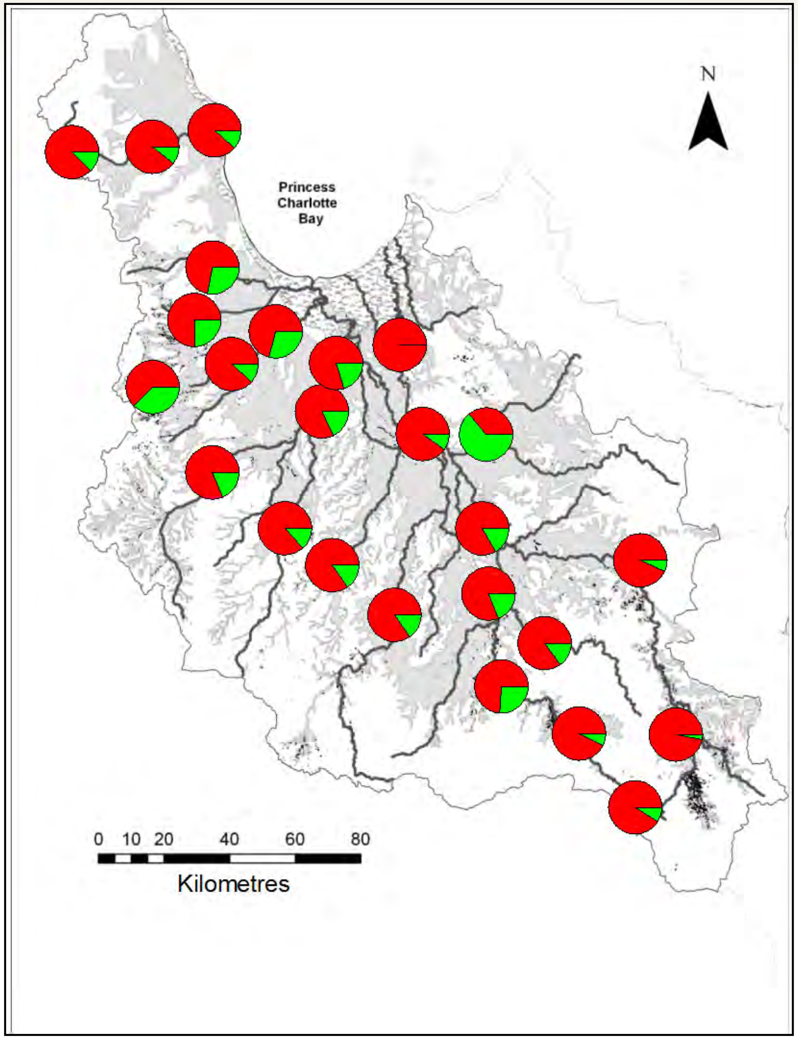


$$A_{Cs}x + B_{Cs}y + C_{Cs}z = D_{Cs},$$
$$A_{Pb}x + B_{Pb}y + C_{Pb}z = D_{Pb},$$
$$x + y + z = 1$$

$$MMD = \left|\frac{D_{Cs} - M_{Cs}}{M_{Cs}}\right| + \left|\frac{D_{Pb} - M_{Pb}}{M_{Pb}}\right|$$

Dominant erosion process in the catchment

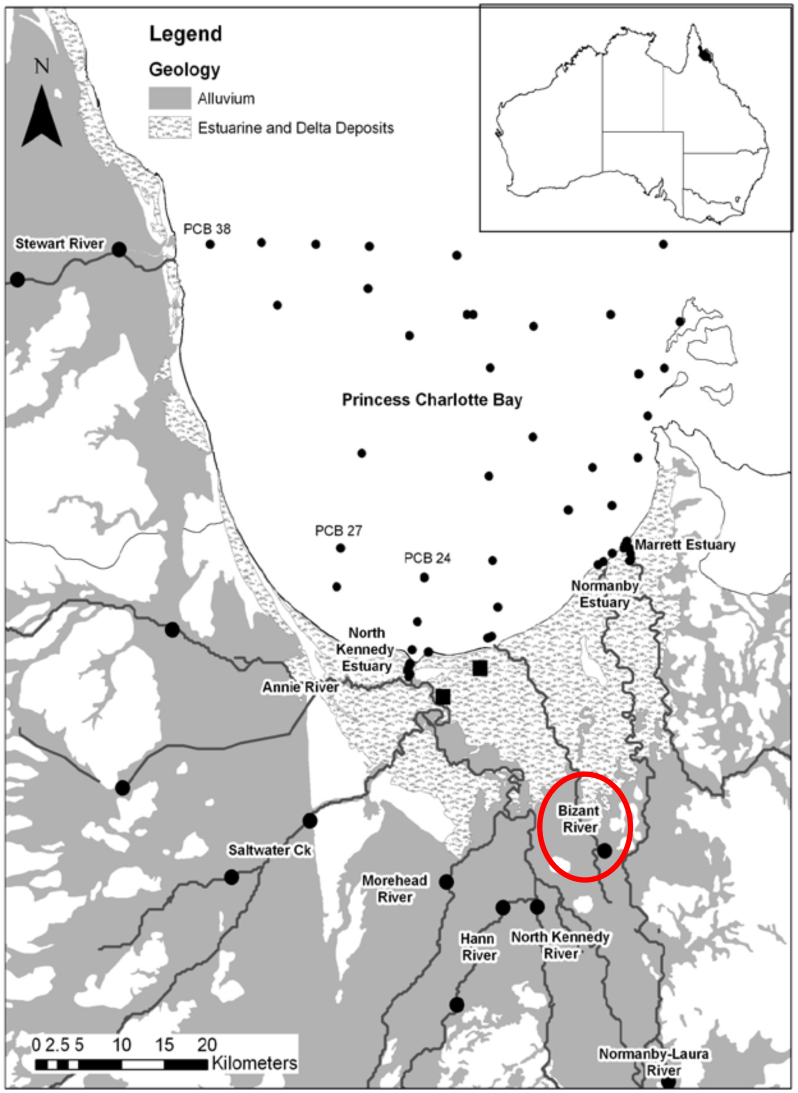
- Most (>83%) of the fine (<10μm) sediment being transported along the main stem of the rivers draining into Princess Charlotte Bay originates from subsoil erosion.
- Reject the hypothesis that surface soil erosion dominates the supply of fine (<10um) sediment in the river systems draining into Princess Charlotte Bay

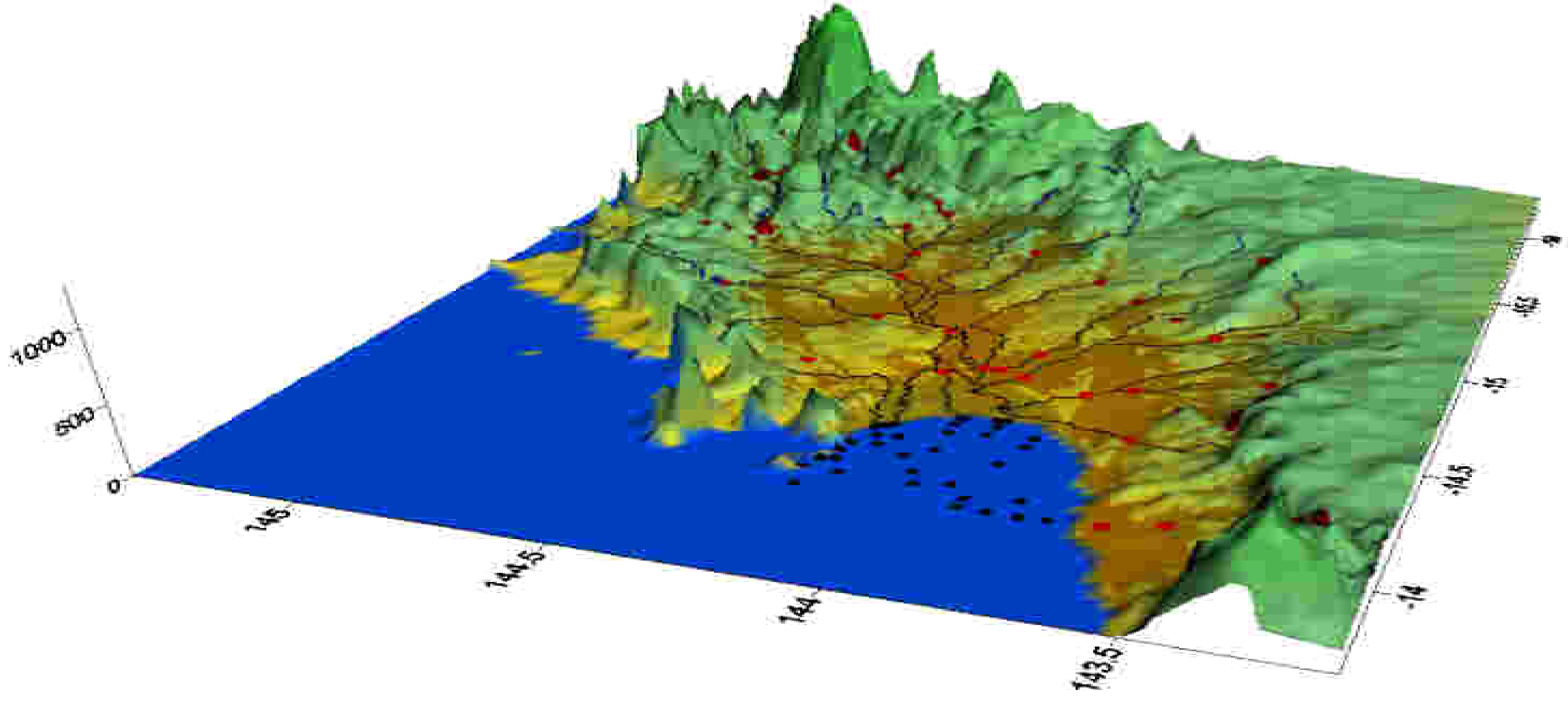


Dominant erosion process in tropical Australia

Tropical Australian studies that have used radionuclide tracers to estimate relative surface soil contributions to the lower catchment			
Catchment	Mean Surface Soil Contribution %	Tracer	Reference
Daly	11	^{137}Cs	Wasson et al., (2010)
Ord	10	^{137}Cs	Wasson et al., (2002)
Upper Fitzroy	20	^{137}Cs and $^{210}Pb_{ex}$	Hughes et al., (2009)
Herbert	50	^{137}Cs	Bartley et al., (2004)*
Herbert	20	^{239}Pu	Tims et al., (2010)*
Bowen	17	^{137}Cs, $^{210}Pb_{ex,}$ C	Wilkinson et al., (2012)
Mitchell	3	^{137}Cs	Caitcheon et al., (2012)
Daly	1	^{137}Cs	Caitcheon et al., (2012)
Cloncurry	0	^{137}Cs	Caitcheon et al., (2012)
PCB rivers	16 ± 2	^{137}Cs and $^{210}Pb_{ex}$	This study

Geochemistry and provenance of sediments from Princess Charlotte Bay




1000
500
0
145
144.5
144
143.5
-14
-14.5
-15
-15.5
-16

The Rivers

Annie
Bizant
North Kennedy
Hann
Morehead
Normanby
Saltwater
Stewart

Coastal Plain

Marine Carbonate

Quartz

The Rivers

Annie
Bizant
North Kennedy
Hann
Morehead
Normanby
Saltwater
Stewart

Cores collected from 46 sites across the bay

All samples were sieved to remove any coarse fragments (>500 um)

- shell and coral fragments

- composited to characterise the marine carbonate component

Queensland Government Department of Science, Information Technology, Innovation and the Arts (DSITIA) Chemistry Centre,

Coupled Plasma-Mass Spectrometry (ICP-MS) for the major element

Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) for the trace elements

Table1: Correlation coefficients for elements measured on surficial sediment samples collected from PCB and its estuaries.

Element	SiO_2	Al_2O_3	CaO
SiO_2	1.00	-0.21	-0.84
TiO_2	-0.09	0.94	-0.44
Al_2O_3	-0.21	1.00	-0.34
Fe_2O_3	-0.23	0.98	-0.32
MgO	-0.86	0.38	0.59
Na_2O	-0.49	0.57	0.12
CaO	-0.84	-0.34	1.00
K_2O	0.05	0.90	-0.55
P_2O_5	-0.85	0.50	0.54
Zn	-0.04	0.80	-0.37
As	0.00	0.49	-0.24
Ba	0.13	0.42	-0.33
Ce	0.07	0.44	-0.28
Co	-0.08	0.78	-0.33
Cr	-0.24	0.82	-0.22
Dy	0.01	0.85	-0.47
Er	0.01	0.79	-0.45
Eu	-0.04	0.80	-0.38
Gd	-0.05	0.76	-0.35
Ho	-0.01	0.84	-0.45
La	0.00	0.59	-0.28
Lu	0.08	0.64	-0.44
Mn	0.01	0.59	-0.34
Nd	0.00	0.64	-0.31
Pr	0.01	0.63	-0.31
Sm	0.01	0.73	-0.38
Sr	-0.78	-0.36	0.95
Tb	-0.04	0.82	-0.40
Th	-0.07	0.86	-0.41
Tm	0.03	0.75	-0.45
U	-0.45	0.44	0.21
V	-0.22	0.96	-0.33
Y	-0.04	0.80	-0.39
Yb	0.04	0.74	-0.45

Modelling the geochemistry

- Principle component analysis
  - identify the key geochemical components present in the sediments.
- The Kruskal–Wallis H-test (source samples)
  - identify the geochemical properties which distinguish between the source end members (each of the nine rivers, quartz silt/sands and marine carbonates).
- Linear discriminant analysis (source samples)
  - to identify the optimum combination of properties which distinguished between the sources.
  - The percentage of the sources correctly classified by each individual geochemical property was assessed.
  - Parameters were added such that with each addition the number of sources correctly classified was maximised.

The model

$$MMD = \sum_{i=1}^{n} \left| \left(C_i - \left(\sum_{s=1}^{m} P_s S_{si} \right) \right) / C_i \right|$$

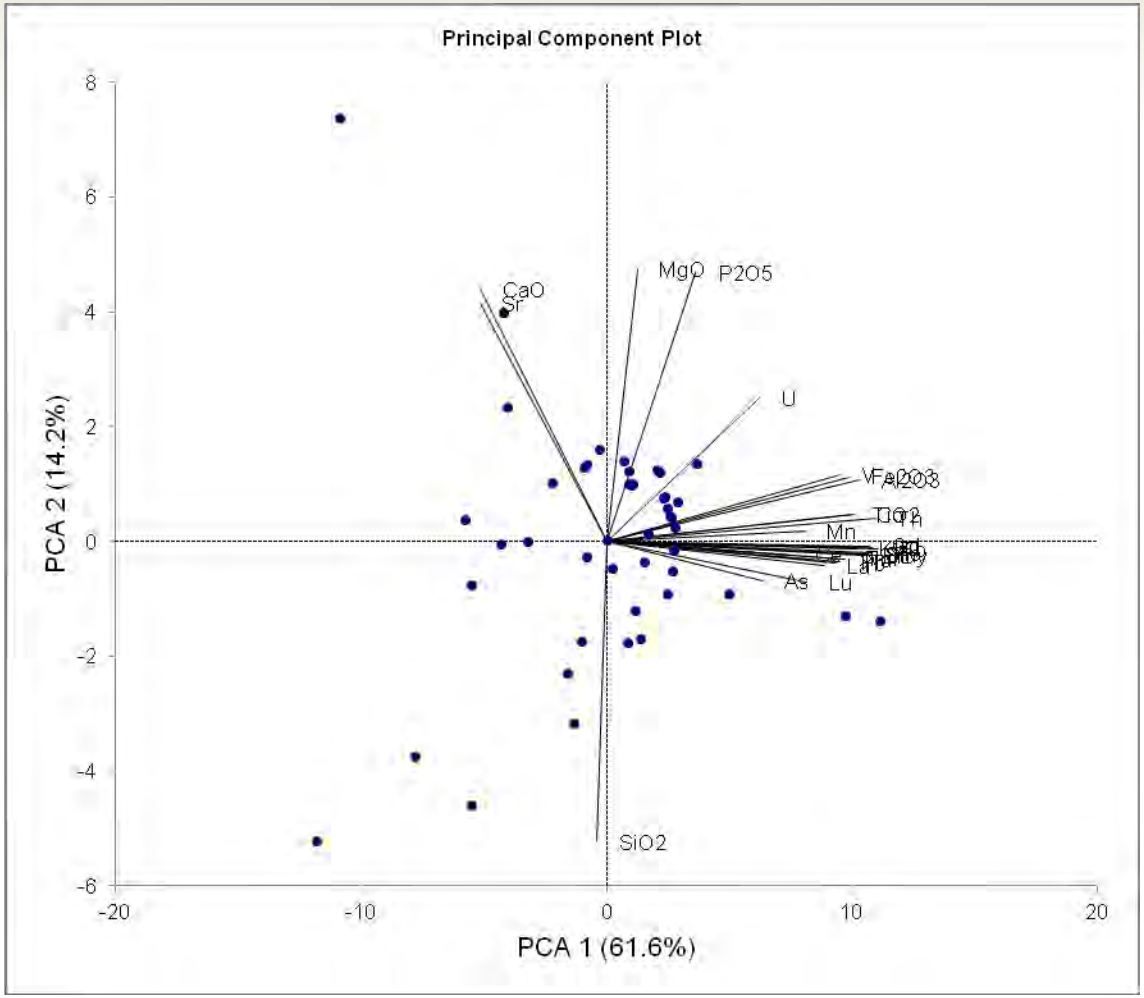
Test of the fit

$$GOF = 1 - \left(\frac{1}{n} * MMD \right)$$

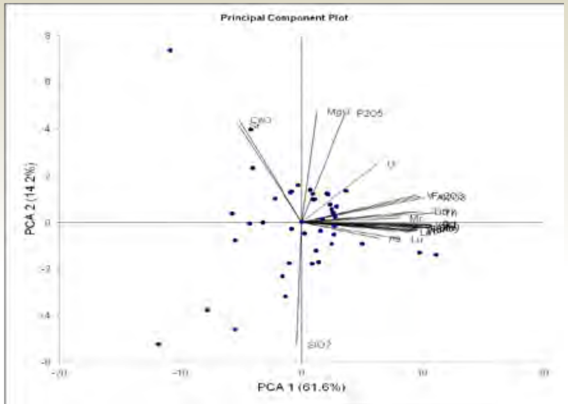
1 is a perfect fit

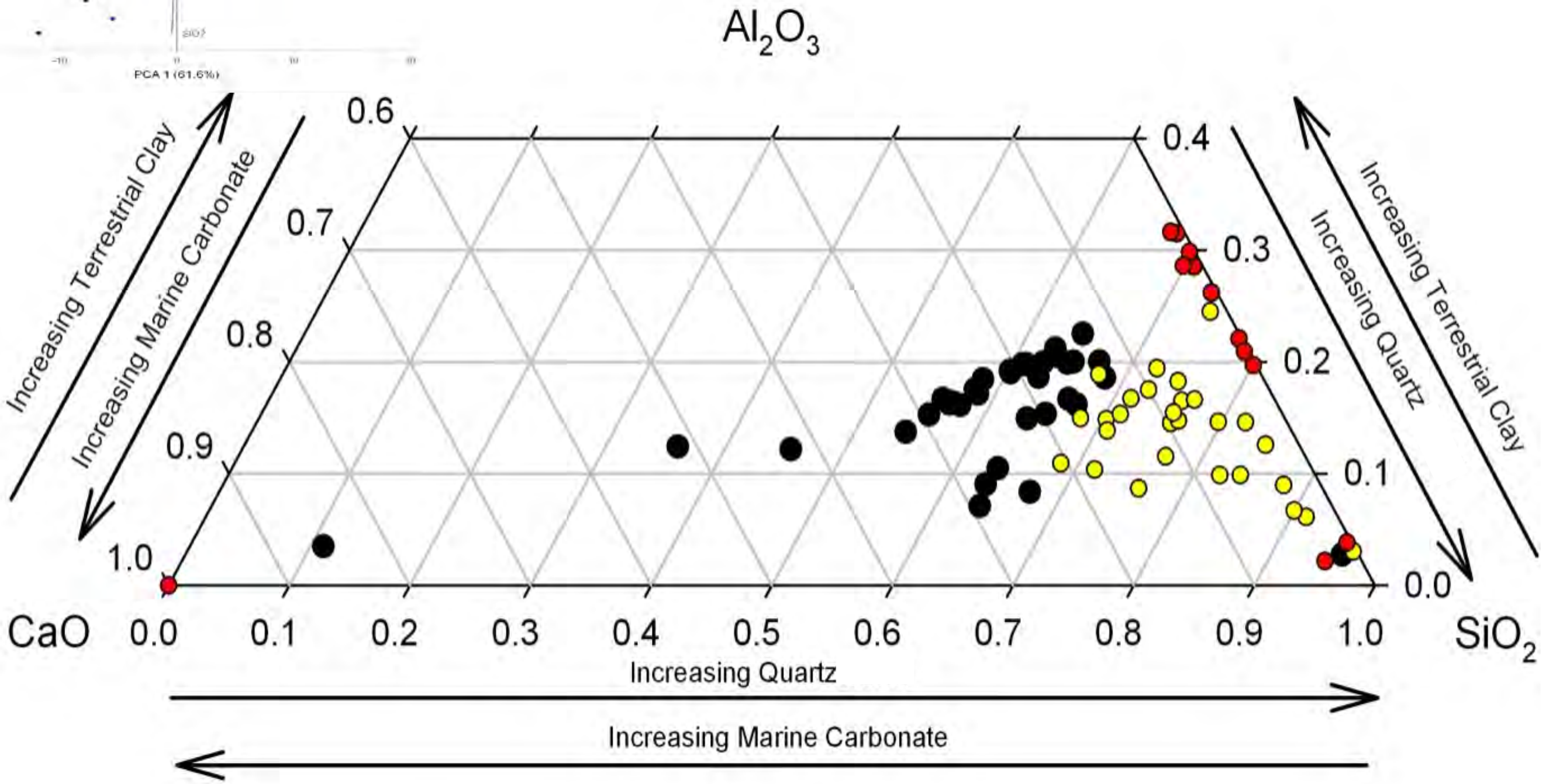
Average for 64 bay and estuarine samples 0.93 ± 0.02

marine carbonate and quartz



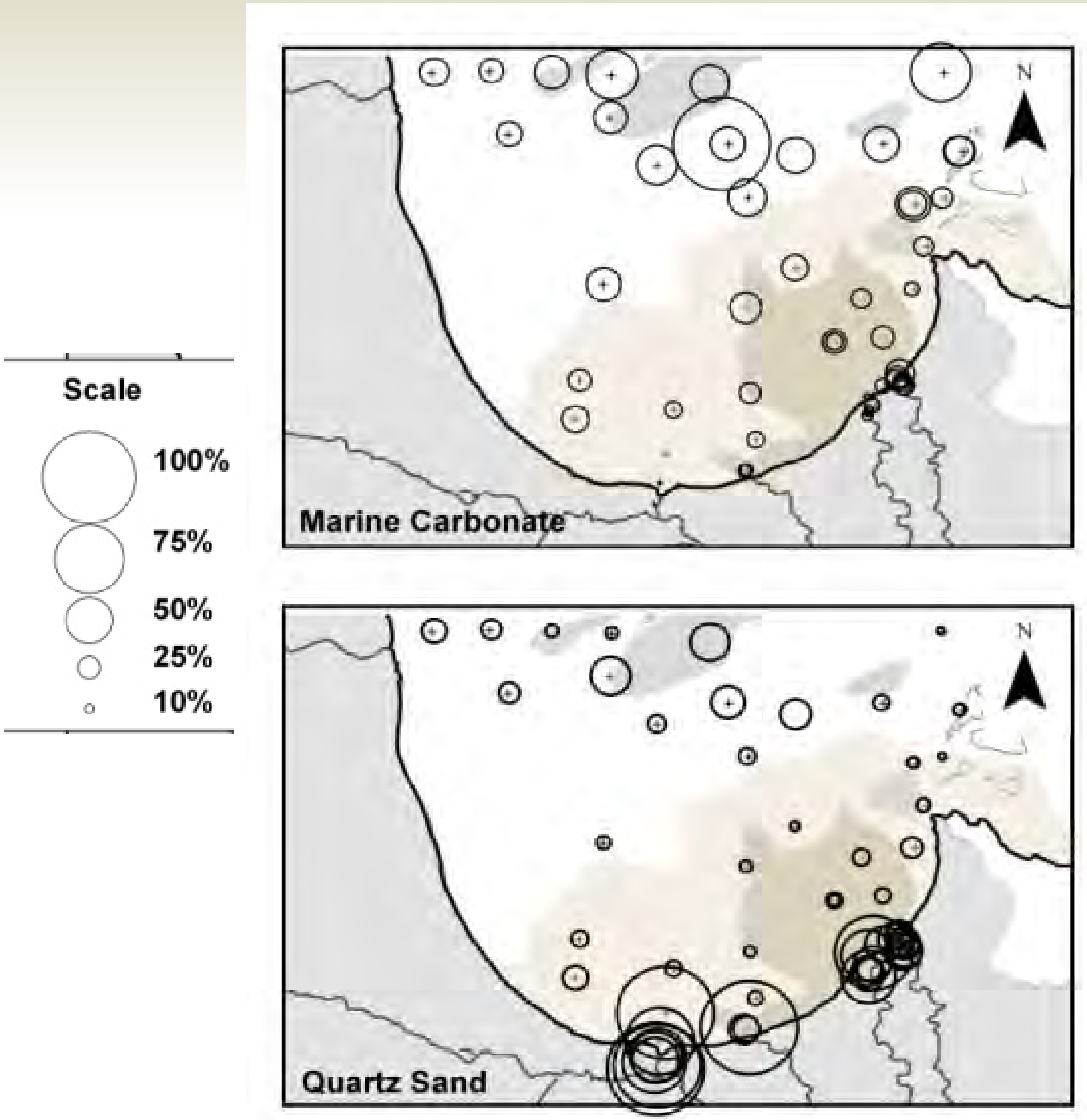
marine carbonate and the clay associated elements


Principal Component Plot
PCA 1 (61.6%)
PCA 2 (14.2%)


Al_2O_3
0.6
0.7
0.8
0.9
1.0
0.4
0.3
0.2
0.1
0.0
CaO
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
SiO_2
Increasing Terrestrial Clay
Increasing Marine Carbonate
Increasing Terrestrial Clay
Increasing Quartz
Increasing Quartz
Increasing Marine Carbonate

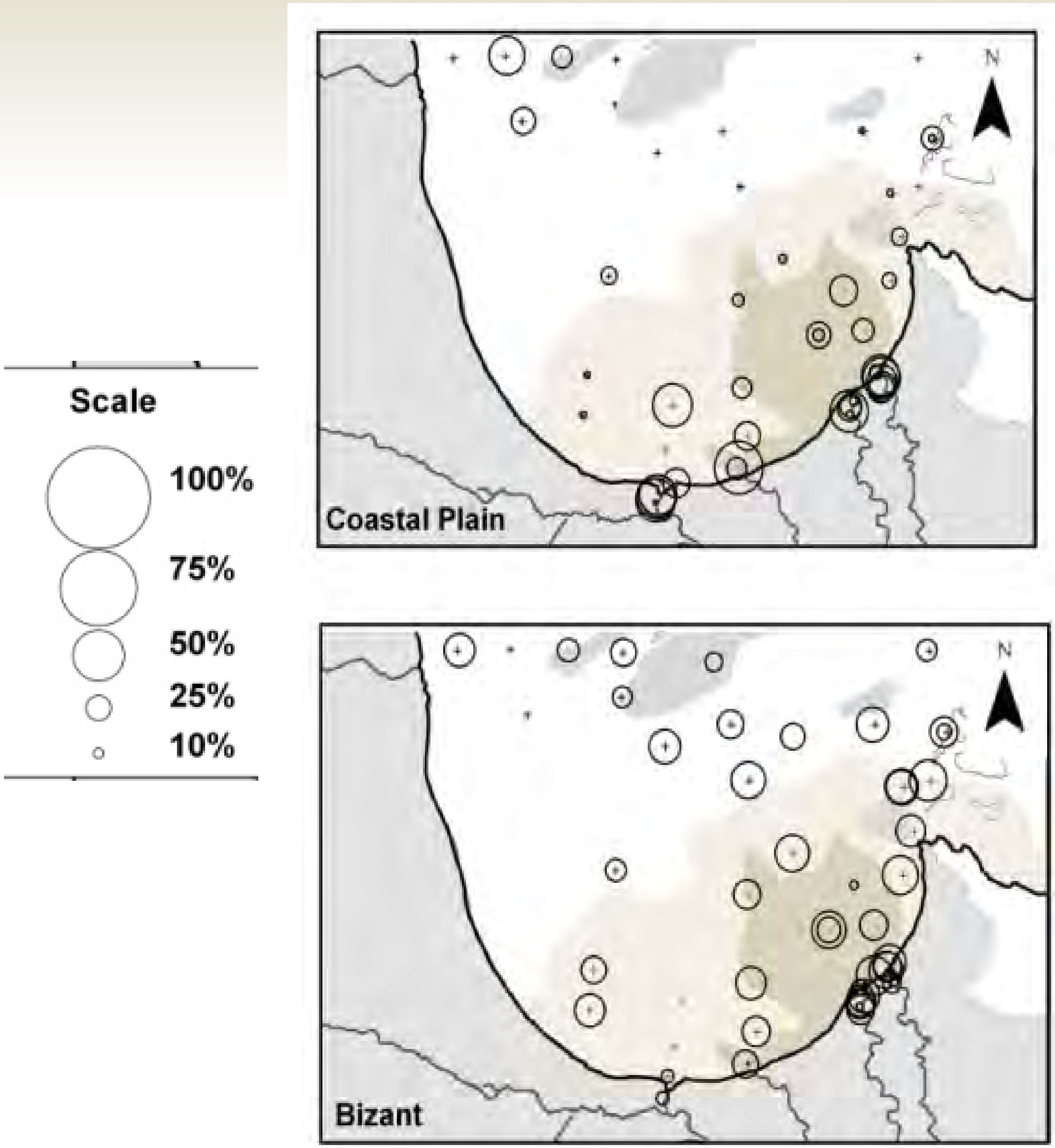
Suite of elements providing the best discrimination between sources

	Kruskal–Wallis H-test		*Percent (%) correctly classified*	
	H-value	*P*-Value	*Individual*	*Cumulative*
V	31.9	<0.001	55.3	55.3
TiO_2	33.2	0.001	53.2	70.2
CaO	24.2	0.002	40.4	76.6
K_2O	25.7	<0.001	51.1	91.5
Yb	24.0	0.002	44.7	93.6
U	29.1	<0.001	46.8	97.9
Th	18.2	0.020	38.3	97.9
Pr	17.3	0.030	36.2	100
SiO_2	22.8	0.004	34.0	100
La	18.0	0.021	40.4	100



28 ± 3%

26 ± 3%



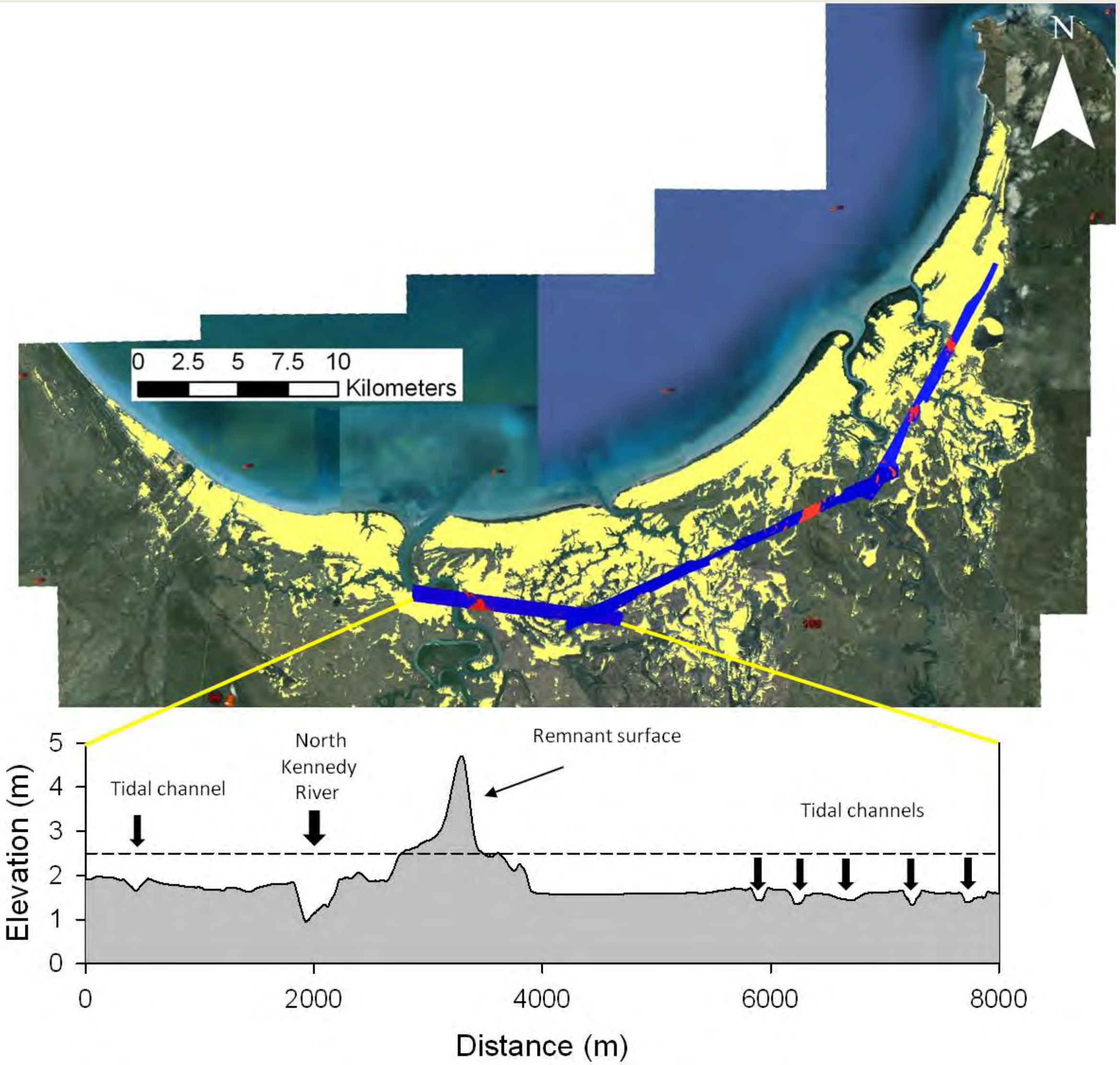
14 ± 2%

24 ± 2%

The Rivers

~10%

Annie
North Kennedy
Hann
Morehead
Normanby
Saltwater
Stewart



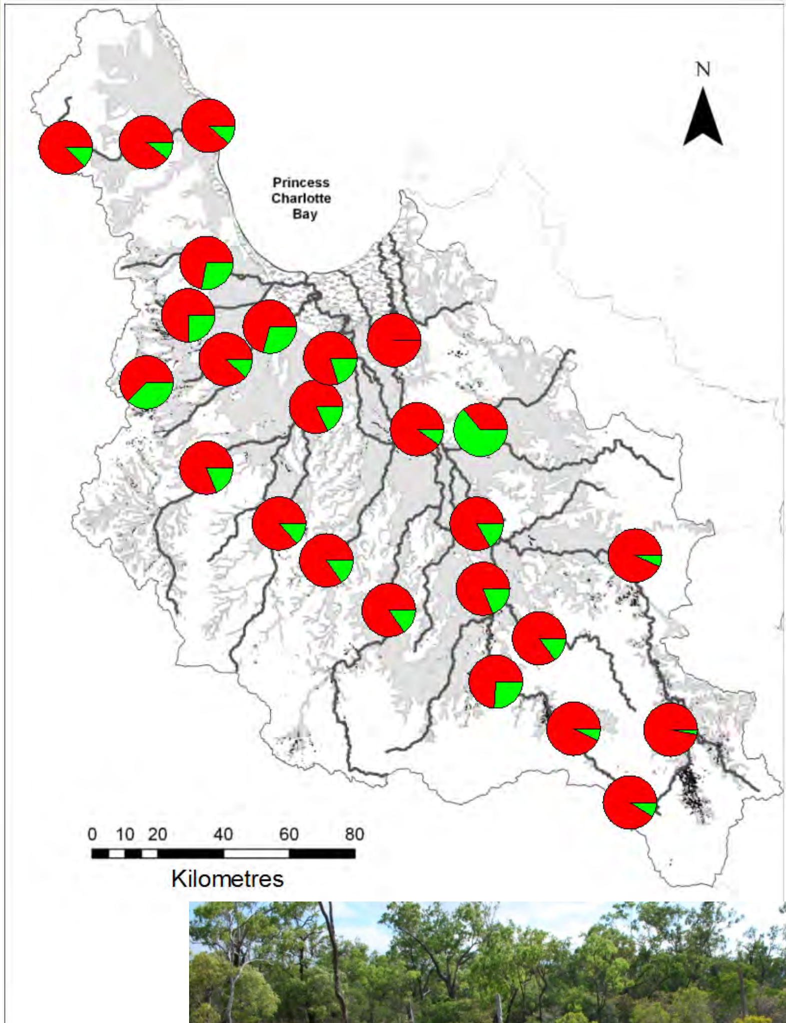
LiDAR data

Conservatively
0.71± 0.08 m of erosion

175Mt to 220Mt
has been eroded from this area.

Optical dating

In the last 500 to 1000 years


N
Princess
Charlotte
Bay
0 10 20 40 60 80
Kilometres