

The Sources Of Sediment In The Darling-Barwon Rivers: Some Preliminary Results

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ABSTRACT: *Major element chemistry and naturally present magnetic minerals are used to trace the source of sediment in the Darling-Barwon Rivers. Specifically, we show that basalt derived sediment is likely to be a major source, and by inference a significant source of particulate bound phosphorus. Data from the Barwon-Namoi confluence show that the contemporary sediment and phosphorus contribution by the Namoi River may be as much as 30-40%. Data from undated core sediment indicate that a long term average of <10% is likely.*

1. INTRODUCTION

The massive algal bloom that occurred along the Darling River in late 1991 resulted in a considerable increase in research to determine the causes of such blooms. One of these studies is a collaborative effort between the Water Studies Centre at Monash University, the Murray-Darling Freshwater Research Centre at Albury, and the CSIRO, Division of Water Resources, Canberra. The study is partially funded by the Murray-Darling Basin Commission as part of the Natural Resources Management Strategy, and aims to understand the sources and cycling of nutrients, as well as the conditions that promote algal growth in the Darling-Barwon Rivers.

One of the objectives of the CSIRO part of the study is to identify the sources of phosphorus reaching the river. We have concentrated on tracing phosphorus associated with fine suspended sediment that makes up about 95% of the rivers' sediment load (Woodyer, 1978).

Our approach to spatial sediment tracing is to measure the properties of sediment from major tributaries, and the main channel, to determine whether or not sediment characteristics can be distinguished by major element chemistry and magnetic mineral properties. If the tributaries can be distinguished from the main channel, then it is usually possible to quantify relative tributary sediment contributions.

Recent New South Wales Department of Land and Water Conservation reports have indicated that the Namoi River is a major source of particulate associated phosphorus reaching the Barwon River (Houldsworth, 1995; Daly, 1994). In this paper we

present quantitative estimates of the proportion of sediment, and associated phosphorus delivered to the Barwon-Namoi confluence from each tributary. A prior study undertaken by the authors (Caitcheon *et al.*, 1995) has shown that phosphorus-rich basalt soils in the headwaters of the Namoi River are the major source of sediment associated phosphorus. We attempt to estimate the contribution of basalt derived soils to sediment in the Darling-Barwon Rivers.

2. SAMPLING AND MEASUREMENTS

Two suspended sediment sampling runs from Wilcannia to Mungindi were undertaken at the beginning of the study, but since then this has not been an option due to very low, or nonexistent flow. Bed and bank sediment samples were collected from major tributaries, and along the Darling-Barwon upstream and downstream of the tributaries in late 1994 when there had been no flow in the river system for several months. Fine sediment was collected from what appeared to be recently deposited mud on sloping banks. Core samples were taken from an upstream flood terrace, and a downstream infilled channel on the Barwon River at the Namoi confluence, as well as from a low bench beside the channel of the Namoi River. All of the core sites are below the bank full level, so they would be inundated during less than bank full floods, although sediment deposition rates are probably low. We are presently attempting to date the fine sand in the mainly clay cores using optically stimulated luminescence.

All samples were sonified, and underwent settling in a water column to recover the <10 μm fraction (clay and very fine silt). This is the fraction that will contain most of the particle associated phosphorus.

Major and minor elements were measured by X-ray fluorescence analyses using standard methods (e.g. Norrish, 1968).

Magnetic measurements included susceptibility and isothermal remanence. Low frequency (0.45 kHz) specific susceptibility (χ) was measured with a Bartington meter and MS2B sensor. Specific magnetic susceptibility is approximately proportional to the concentration of all magnetic minerals in a sample. Isothermal remanent magnetisations (IRM) were imparted at 850 milli Tesla with a Molspin pulse magnetiser, and the resulting magnetisation

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measured with a Molspin fluxgate magnetometer. IRM measurements are sensitive to magnetic minerals that remain magnetised after being subjected to artificial magnetic fields. These parameters are generally representative of magnetic mineral assemblages (Caitcheon, 1993; Oldfield, 1991).

3. SEDIMENT TRACING RESULTS

3.1 Mineralogy

The mineralogy of the $<10\mu\text{m}$ fraction of sediments from the Darling-Barwon Rivers is dominated by clays and quartz, with minor amounts of residual feldspar (Woodyer 1978; Douglas 1993; Donnelly *et al.*, in prep.). The clays consist predominantly of a mix of kaolinite, smectite and illite. Smectite is produced by the weathering of basic rocks (Deer *et al.*, 1980), and its presence in Darling-Barwon sediments is indicative of a basaltic soil source (Woodyer, 1978). Kaolinite and illite are typically produced by the weathering of feldspars and micas. As these minerals are present in a variety of rock types, their presence in the Darling-Barwon sediments is not indicative of any particular rock source.

3.2 Quantifying The Basalt Contribution To Barwon River Sediments

Phosphorus-rich Tertiary basalt soils were found to be the dominant source of particulate-bound P in Chaffey Catchment in the headwaters of the Namoi River. Tertiary basalts are present in the headwaters of most of the tributaries of the Darling-Barwon, including the Namoi, Gwydir, MacIntyre and Culgoa Rivers. In this section we attempt to quantify the contribution of basalt derived sediment reaching the Darling-Barwon Rivers.

Concentrations of Al_2O_3 and SiO_2 in the $<10\mu\text{m}$ fraction of sediments collected from along the main channel of the Darling-Barwon Rivers are shown in Figure 1. Average Al_2O_3 and SiO_2 contents of the major clay minerals present in Darling-Barwon sediments (kaolinite, illite, smectite) are also shown in this figure, calculated from data in Norrish and Pickering (1983). There is a good correlation ($r^2=0.96$) between Al_2O_3 and SiO_2 in the sediment data indicating a consistent mix of minerals. The regression line tends towards 100% SiO_2 (quartz) in one direction, and intercepts a line joining smectite+illite to kaolinite in the other. The intercept between the regression line and that joining the clay components can be used to estimate the mean kaolinite content of the sediment. The data presented in Figure 1 are consistent with kaolinite being on average about 50% of the clays (if we ignore the

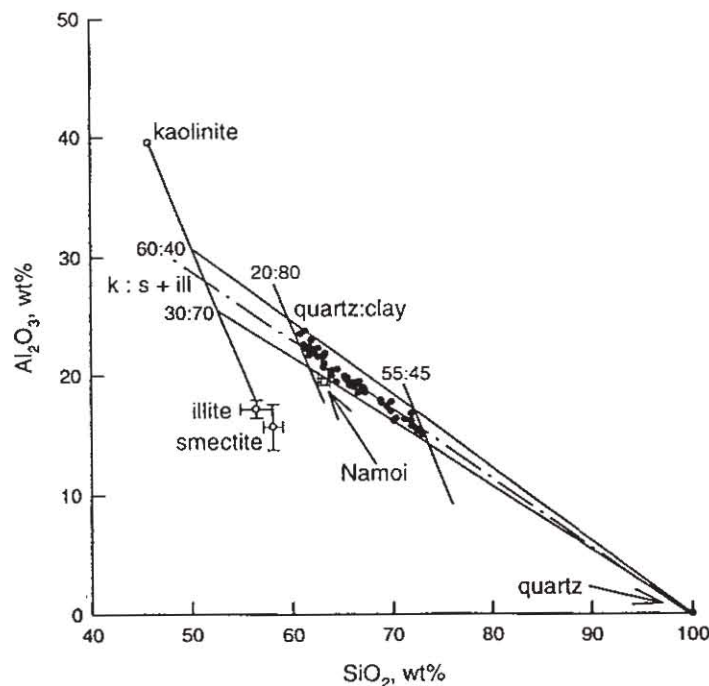


Figure 1. Concentrations of Al_2O_3 and SiO_2 in the $<10\mu\text{m}$ fraction of sediments collected from along the main channel of the Darling-Barwon Rivers.

effects of a minor amounts of residual feldspars). The scatter in the data about the regression line indicates that the kaolinite content varies from about 30-60% of the clays. The spread in the data along the regression line is a result of variations in the ratio of quartz to clay in the sediments, and indicates that this ratio varies from 20:80 to 55:45. As quartz is not produced by the weathering of basalts, this provides an upper limit of about 80% for the contribution from basalt soils to the Darling-Barwon sediment.

The clay chemistry of the sediments can be examined further by plotting the Al_2O_3 , $Na_2O + CaO$, and K_2O data as molar proportions in a ternary diagram (Figure 2). The average clay mineral compositions are also shown in this figure, along with the chemical index of alteration (CIA). This index can be used to indicate the degree of weathering of the aluminosilicate minerals (McLennan, 1993). Unweathered aluminosilicate minerals have CIA values of about 50, whereas clay minerals typically have values of between 75-100. All of the $<10\mu m$ fraction of the sediment samples from the Darling-Barwon Rivers have CIA values of >75 , indicating that they contain little or no residual aluminosilicate minerals. The sediment data lies on a line pointing at kaolinite, and passing between the average smectite and illite compositions. The left-right position of the bottom end of the line is controlled by the relative proportions of smectite and illite, and the vertical spread shows the relative proportions of kaolinite and smectite plus illite. These data indicate that the clays in the Darling-Barwon channel consist of a relatively uniform 60:40 mix of smectite:illite, with kaolinite contents (as a proportion of the clays) ranging from 30 to 60%.

Smectite is primarily produced from the weathering of basaltic rocks, and so we can use the smectite content of the Darling-Barwon sediments to estimate a lower limit for the contribution of basaltic soils from the uplands. A minimum of 45% of the $<10\mu m$

sediment sample is clay minerals. Kaolinite is a maximum of 60% of the clay minerals. Of this remaining 40% smectite contributes a minimum of 22%. Therefore, the minimum amount of smectite is 10%. We conclude from this, and the data presented above, that basalt derived sediment contributes 10-80% of the $<10\mu m$ sediment in the Darling-Barwon Rivers.

The geochemical data show that basalt derived sediment is present in the river system. However, the range is large, so it would be useful to better define the extent of the contribution. In Table 1 are magnetic mineral data from the Barwon River, and catchments that (i) only contain basalt rocks, (ii) the Bogan River catchment, and (iii) soils developed on sedimentary rocks in the Chaffey Reservoir catchment (Namoi basin). The basalt derived sediment data are from the Mooki River in the Namoi Basin, and Rocky Creek on the Darling Downs near Toowoomba. The Bogan River catchment has a range of rock types including, granite, volcanics, metamorphic and sedimentary rocks, but no basalt.

It is evident from the regression coefficients in Table 1 that the sediments from the Barwon River and the basalt are very similar. From this we conclude that basalt derived sediment is making a major contribution to the Barwon River sediments. However, it should be noted that while we believe that these results are representative, we do not have data from all of the potential rock types in the basin. Therefore our conclusion should be regarded as indicative until more data are available.

Table 1. IRM_{850} vs. χ regression coefficients.

	Regression Coefficient	r ²
Barwon River	13.8±0.6	0.91
basalt derived sediments	12.9±2.3	0.73
Bogan River	8.2±0.3	0.96
sedimentary rock soils	5.3±1.7	0.97

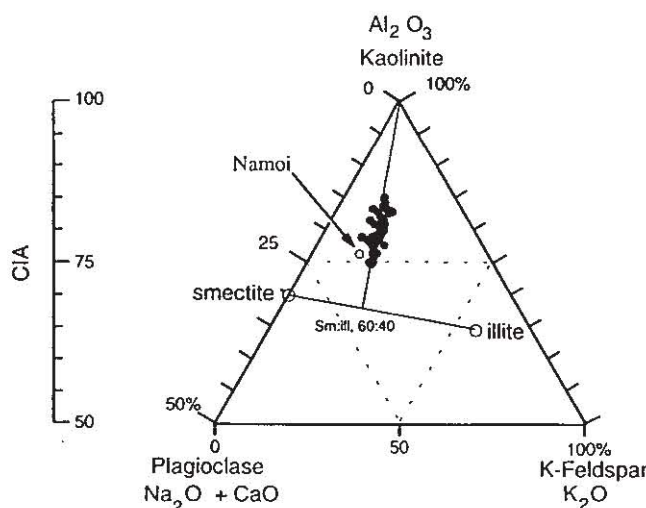


Figure 2. Al_2O_3 , $Na_2O + CaO$, and K_2O in the Darling-Barwon Rivers sediment.

The filled circles are from the main channel.

3.3 Quantifying Relative Sediment And P Contributions From The Namoi River

Major element data from 16 <math> < 10 \mu\text{m}</math> sediment samples collected from the Namoi River have been averaged and are presented in Figures 1 and 2. These data indicate that the Namoi sediments tend to be more smectite rich than the main channel sediments. In general smectite contains more Mg than the other clay minerals present. Consequently, we have used the $\text{MgO}/\text{Al}_2\text{O}_3$ ratio to determine the relative sediment contribution of the Namoi to the Barwon River (see Figure 3). The mean $\text{MgO}/\text{Al}_2\text{O}_3$ ratio for sediments collected upstream of the Namoi is 0.072 ± 0.002 ($n=12$), and downstream this ratio is 0.091 ± 0.004 ($n=11$). The mean $\text{MgO}/\text{Al}_2\text{O}_3$ ratio in Namoi sediments is 0.116 ± 0.003 , so the relative sediment contribution from the Namoi to the Barwon is $43 \pm 10\%$.

Table 2. Mean magnetic parameter values from the core data shown in Figure 4.

	χ	IRM_{850}
Barwon River	0.174 ± 0.007	1.06 ± 0.14
Barwon upstream	0.175 ± 0.003	0.96 ± 0.05
Namoi	0.338 ± 0.016	2.84 ± 0.17

from 0.04% to 0.11%, with a mean of $0.068 \pm 0.002\%$ ($n=74$). Concentrations in the Namoi are higher, ranging from 0.07% to 0.23%, with a mean of $0.122 \pm 0.001\%$ ($n=16$). Average concentrations in the Barwon above and below the Namoi junction are $0.053 \pm 0.001\%$, and $0.076 \pm 0.004\%$ respectively. These data indicate a $33 \pm 6\%$ contribution of particle bound P from the Namoi to the Barwon, and are consistent with the $43 \pm 10\%$ sediment input calculated above. This result shows that at the Barwon-Namoi confluence, the Namoi probably

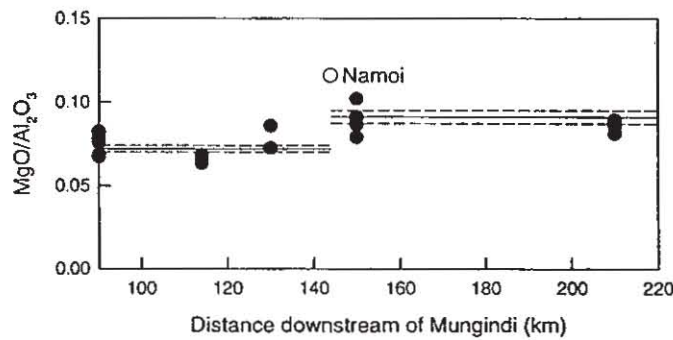


Figure 3. $\text{MgO}/\text{Al}_2\text{O}_3$ ratios from the Barwon and Namoi Rivers. The solid and dashed lines are the mean and standard errors respectively.

Magnetic measurements made on the core samples from the Barwon-Namoi confluence are shown in Figure 4. Relative average sediment contributions are estimated from the mean values of each parameter, given in Table 2. The relative sediment contributions based on the χ and IRM_{850} mean values are $0 \pm 5\%$ and $5 \pm 8\%$ respectively. Both of these values are consistent given the standard errors. However, the Namoi contribution determined from the magnetic data is substantially less than that calculated from the element chemistry. At this stage all that we can conclude is that the contemporary sediment contribution from the Namoi River may be as high as 40%, but the core data indicate that the long term average may be somewhat less than this. It is worth noting that the total proportionate water contribution from the Namoi to the Barwon is 29%, calculated from 1968-1994 flow data.

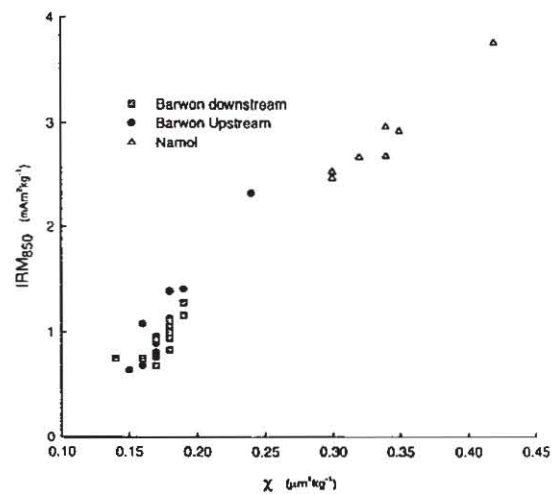


Figure 4. Core data from the Barwon-Namoi confluence.

Sediment associated phosphorus concentrations (wt% P) in the main channel are generally low, ranging

makes a significant contribution of sediment associated phosphorus, but it is not the dominant source.

4. CONCLUSION

Based on the element chemistry, the contemporary sediment, and associated phosphorus contributions from the Namoi River to the Barwon are about 30-40%. The magnetic data from the cores indicate a Namoi contribution of <10%. It may be possible to reconcile these two different estimates after geochemical measurements, and further sampling of the cores is completed. Dating of the core sediments will provide temporal limits for our estimate of the long-term average contribution.

The geochemical and magnetic data indicate that basalt derived sediment is probably a major source of sediment in the Darling-Barwon river system, and by inference, a significant source of particulate bound phosphorus. This conclusion will be tested further as more data become available. However, the implications for river and catchment management are far reaching if it can be conclusively demonstrated that sediment associated phosphorus substantially originates from natural sources.

5. REFERENCES

- Caitcheon, G.G., Donnelly, T.H., Wallbrink, P.J., and Murray, A.S. (1995) Nutrient and sediment sources in Chaffey Reservoir Catchment. *Aust. J Soil & Water Conservation*, 8, 2, 41-49.
- Caitcheon, G.G. (1993) Sediment source tracing using environmental magnetism: a new approach with examples from Australia. *Hydrological Processes*, 7, 349-358.
- Daly, H. (1994) Central and North Western Regions Water Quality Program: 1993/94. Report on nutrient and general water quality monitoring, Department of Water Resources, TS94.088.
- Deer, W.A., Howie, R.A. and Zussman, J. (1980) An Introduction to rock forming minerals. Longman Group Limited, London.
- Donnelly, T., Olley, J., Murray, A., Caitcheon, G., and Hart, B. The Bourke Weir Pool sediment history and algal blooms (in prep.)
- Douglas, G.B. (1993) Characterisation of suspended particulate mater in Murray-Darling system. PhD thesis, Monash University.
- Houldsworth, B. (1994) Central and North Western Regions Water Quality Program: 1994/95. Report on nutrient and general water quality monitoring, Department of Land and Water Conservation, TS95.088.
- McLennan, S.M. (1993). Weathering and global denudation. *Journal of Geology*, 101, pp 295-303
- Norrish, K. (1968) Some phosphate minerals in soils. *Transactions 9th Conference International Soil Science Society, Adelaide, Vol 2*, J. W. Holmes ed., Angus & Robertson, Sydney, Australia.
- Norrish, K. and Pickering, J.G. (1983) Clay minerals. In 'Soils: an Australian view point', Division of Soils, CSIRO pp281-308. (CSIRO, Melbourne)
- Oldfield, F. 1991. Environmental magnetism - a personal perspective. *Quaternary Science Reviews*, 10, 73-85.
- Woodyer, K.D. (1978) Sediment regime of the Darling River. *Proc. Royal Soc. Vic.*, Vol. 90, Part 1, Symposium on the Murray-Darling System.

