

Using Major Element Chemistry to Determine Sediment Source in the Tarago Catchment: Preliminary Findings

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ABSTRACT

Clay mineralogy and major element chemistry show promise as indicators of sediment source in Melbourne Water's Tarago Reservoir. The catchment supplying the reservoir, which is subject to multiple land use, has two distinct lithologies. Soils sampled from two small sections of differing lithology can be distinguished by their clay mineralogy and the relationships between Al_2O_3 and SiO_2 , and Fe_2O_3 and Al_2O_3 . Initial indications are that near the inlet of the Tarago River into the reservoir, sediment is an even mixture of material derived from the two lithologies, but further down the reservoir the sediment appears to be derived predominantly from the basalt. These findings are preliminary but do suggest that the soils formed on basalt (and used for a variety of agricultural practices) are the predominant source of sediment to the reservoir.

1. INTRODUCTION

The Tarago catchment, located 85 km east of Melbourne (Figure 1) is one of Melbourne Water's supply catchments. The quality of water in Tarago reservoir is significantly lower than from Melbourne Water's other catchments (Jayasuriya et al., 1994) and does not always meet National Health and Medical Research Council (NHMRC) guidelines for drinking water (J. Riddiford, personal communication 1995). Use of the water from the reservoir is currently limited due to its poor quality. However, Melbourne Water's predictions indicate that it will be required as part of

Melbourne's supply system in the near future (Jayasuriya et al., 1994).

Twenty five percent of the 11,400 ha catchment supplying the reservoir is used for agricultural purposes, with forestry and recreational activities occurring on the remainder (Jayasuriya et al., 1994). The major agricultural activities are dairying and grazing, with some potato cropping and hobby farming. Forestry activities are controlled by the Department of Conservation and Natural Resources (DCNR) and the 1987 "Code of Forest Practices for Timber Production" is enforced.

The major source of water to the Tarago Reservoir is the Tarago River which flows through the Tarago -

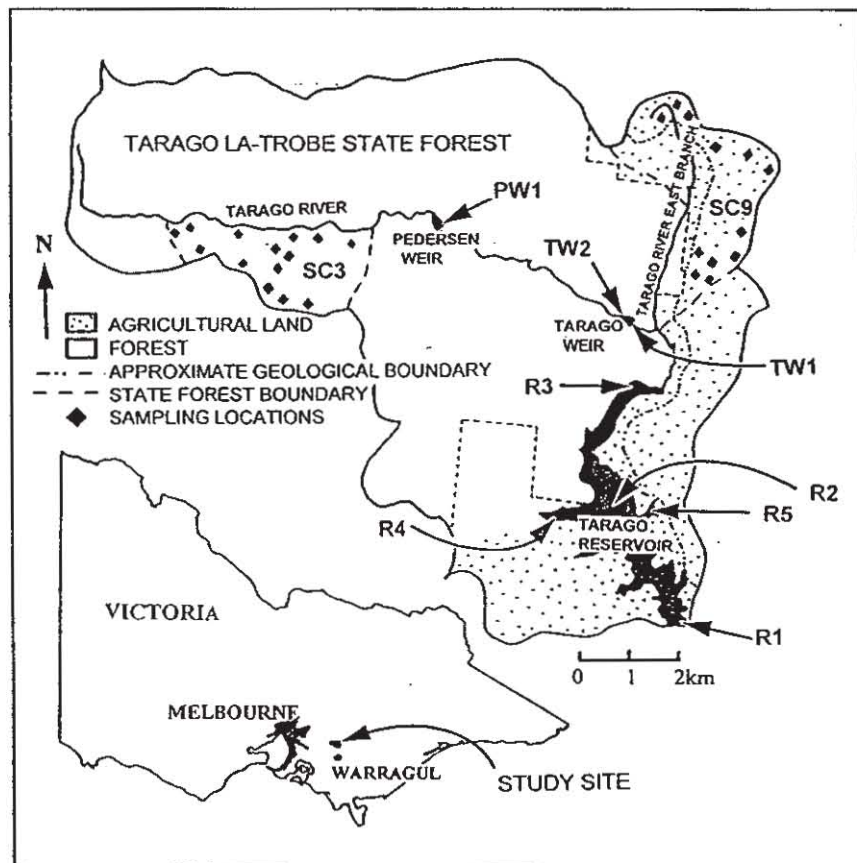


Figure 1. Map showing the location of the Tarago Catchment

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La Trobe State Forest into the northern end of the reservoir. It is joined about 1.5 km upstream of the reservoir by the Tarago River East Branch which flows along the boundary of the State Forest and the agricultural land (Figure 1).

In 1991 there was a minor blue-green algal bloom in the reservoir which increased Melbourne Waters concerns over the supply of nutrients to the reservoir. Phosphate is regarded as the limiting nutrient for algal growth in inland waters (Hecky and Kilham, 1988). It has a strong affinity for soil and organic particles and significant proportion of the phosphate transported in Australian waterways is attached to particles (Oliver, 1993; Cullen, 1995). This particulate phosphorus may subsequently become available for algal growth. This paper reports the preliminary findings of a study which aims to identify the major sources of sediment and associated phosphorus in the Tarago Reservoir.

2. METHODOLOGY

2.1 Potential Sources

Land use, lithology and location have been used to identify three main potential source areas. These are:

- (i) the Tarago La-Trobe State Forest which is largely drained by the Tarago River (Figure 1). The area is covered by wet sclerophyll forest and is subject to logging operations. It is underlain by granite (VandenBerg, 1977) which occasionally outcrops throughout the area;
- (ii) the agricultural land along the north east side of the catchment. This area drains into the Tarago River East Branch and is underlain mainly by basalt (VandenBerg, 1977) although some granite occurs along the edge of the Tarago River East Branch (Figure 1); and
- (iii) the steep hills surrounding the reservoir which drain directly into the reservoir and are underlain by granite on the western side of the reservoir and mainly by basalt on the east.

2.2 Sampling

Sediment mineralogy and major element chemistry have previously been used to distinguish sediments derived from soils formed on different lithologies (see for examples: Klages and Hsieh, 1975; Wall and Wilding, 1976; and Argast and Donnelly, 1987). The initial sampling carried out for this study aimed to determine whether mineralogy and major element chemistry could be used in the Tarago catchment to distinguish sediments derived from soils formed on the granite from those formed on the basalt.

Surface soil samples to a maximum depth of 5 cm were taken from two subcatchments (denoted SC3

and SC9) at the extremities of the catchment. Approximate sampling locations are given in Figure 1. The underlying geology of SC3 is granite and the area is forested. A small section of this subcatchment has been subject to recent logging operations. The majority of SC9 is used for agriculture and the underlying geology is basalt. Samples were collected using a trowel and are presumed to be representative of the surface soil at each site.

An Eckmann grab sampler was used to take samples from the two weirs on the main Tarago River (TW1, TW2 and PW1) and from five different positions in the Reservoir (R1-R5).

2.3 Analytical Methods

Major element concentrations of individual samples were determined by X-ray fluorescence (XRF) spectrometry using a Phillips PW1404 spectrometer according to the procedure outlined in Norrish and Hutton (1969). Finely ground samples were dissolved in molten lithium borate and cast to form a disc. The analysis was carried out on the borate glass disc.

Equal weights of individual samples from within each subcatchment were combined and these bulked soil samples, as well as sample R3 from the reservoir and sample TW1 from Tarago Weir were particle size separated by sieving (using 2 mm, 1.4 mm, 500 μm , 250 μm , 125 μm , 63 μm , 38 μm , 20 μm and 10 μm sieves) and settling (to less than 2 μm).

Clay mineralogy of the <2 μm fractions from the two bulked soils, sample TW1 and sample R3 was determined by X-ray diffraction (XRD) using a Phillips PW-1729 X-ray diffractometer equipped with a Cu-K α x-ray source. Phillips APD search and match software was used to analyse and interpret diffraction patterns.

3. RESULTS

3.1 Clay mineralogy

Differences were found in the clay mineral composition of the soils from SC3 and SC9. Kaolinite, gibbsite and illite were the major clay minerals identified in the soils of SC3. The major clay minerals found in SC9 soils were kaolinite and vermiculite. The clay fraction of Tarago weir sediment contained kaolinite and illite. This is expected as the sediments from Tarago weir are derived from similar granitic soils to those of SC3.

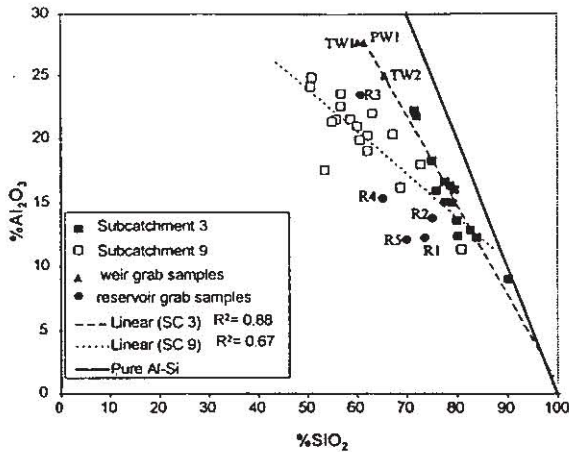


Figure 2. Relationship between Al_2O_3 and SiO_2 concentrations for soils and sediment of the Tarago catchment

The major clay minerals identified in the reservoir sediment (R3) were kaolinite and illite, suggesting a granitic origin.

3.2 Major Element Chemistry

3.2.1 Soils:

In combination, SiO_2 , Al_2O_3 and Fe_2O_3 make up more than 92% of the major element composition of the soils analysed.

SiO_2 and Al_2O_3 :

Concentrations of SiO_2 and Al_2O_3 in the soil samples from sites SC3 and SC9 are plotted in Figure 2. There is a well defined correlation between these elements in the samples from SC3 ($r^2 = 0.88$). This is consistent with the soils being made up of a mainly two component mix:

1. an SiO_2 rich component (quartz), and
2. an Al_2O_3 rich component (clay and/or feldspar).

The spread in the data along the line is the result of differences in the relative contribution of these fractions with the finer clay rich fractions having higher Al_2O_3 contents. Concentrations of SiO_2 and Al_2O_3 are not as well correlated in the samples collected from site SC9 ($r^2 = 0.67$), which indicates that these soils are not a simple two component mix. However the data sets from the two sites are clearly separated, suggesting that it may be possible to distinguish

sediment derived from each site using these parameters.

Al_2O_3 , $CaO^* + Na_2O$, K_2O :

The K_2O , $CaO^* + Na_2O$ and Al_2O_3 data as molar proportions are presented in a ternary diagram in Figure 3. The Chemical Index of Alteration (CIA) (McLennan, 1993) is shown on the left hand side of this figure. This index indicates the degree of weathering of the aluminosilicate minerals in soils. CIA values of 45-55 indicate almost no weathering; a value of 100 indicates extreme weathering with complete removal of Na_2O , K_2O and CaO^* . The soil samples from both sites have high CIA values, most samples being above 80. This indicates that the main aluminosilicate minerals in the soils are clays and little residual feldspar is present. Unfortunately, the two data sets plot very closely together in this diagram, despite the fact that they contain different suites of clay minerals (see XRD data). This means that distinguishing sediment derived from the different sites using the Al_2O_3 , $CaO^* + Na_2O$ and K_2O data is not possible.

Fe_2O_3 and Al_2O_3 :

The relationships between Fe_2O_3 and Al_2O_3 concentrations in the soils from both sites are shown in Figure 4.

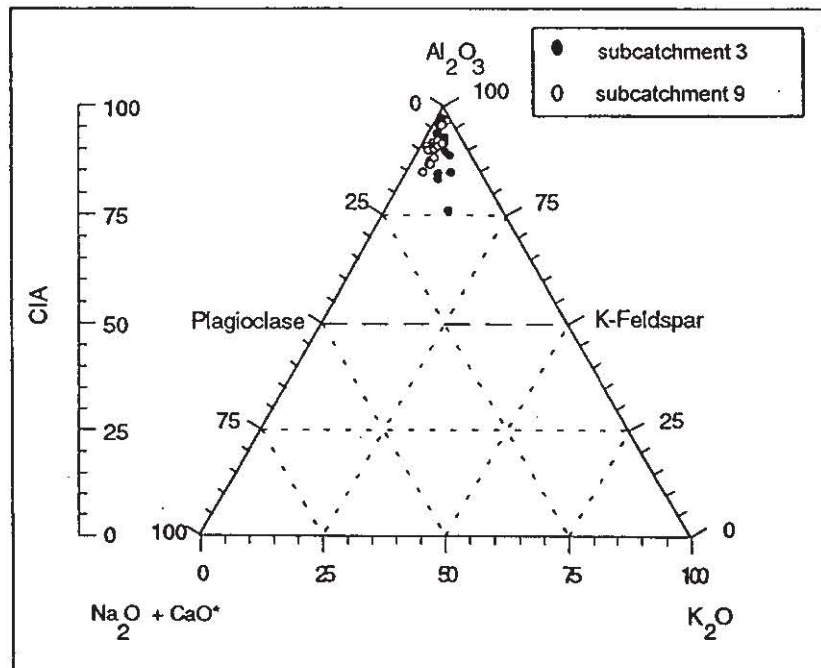


Figure 3. Ternary diagram showing the molar proportions of Al_2O_3 , Na_2O+CaO^* and K_2O in the soils of SC3 and SC9

¹ calcium associated with minerals other than apatite or carbonate

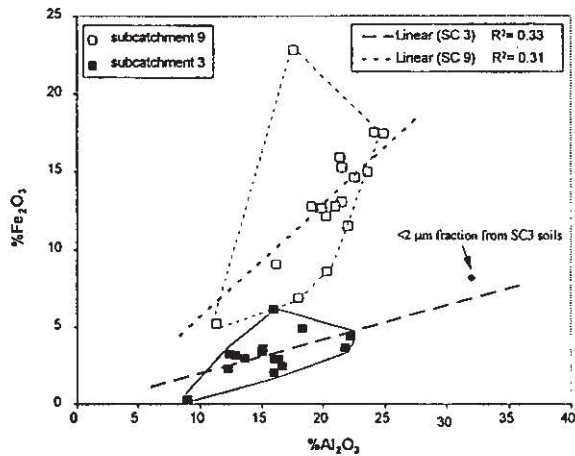


Figure 4. Relationship between Fe_2O_3 and Al_2O_3 concentrations for the soils of SC3 and SC9

The concentration of Fe_2O_3 does not correlate well with the concentration of Al_2O_3 for the soils of either SC3 or SC9 ($r^2 = 0.33$ and 0.31 respectively). However the soils from each subcatchment form two distinct fields suggesting that these parameters may provide a signal by which we can distinguish sediment derived from the two areas. Al_2O_3 and Fe_2O_3 are well correlated ($r^2 = 0.98$) in the particle size fractions from the bulk SC3 soil (Figure 5). Similar correlated increases in Al_2O_3 and Fe_2O_3 concentrations have been observed in other non-aggregated soils (Olley and Murray, unpublished data). These data suggest that mixing and particle size separation of the SC3 soils by fluvial transport will produce sediment in which Al_2O_3 and Fe_2O_3 are correlated. As would be expected this regression passes through the field defined by the bulk soils data (Figure 6). Al_2O_3 and Fe_2O_3 are less well correlated in the particle size fractions derived from the SC9 bulked soils ($r^2 = 0.70$), however the regression also passes through the field defined by the bulk soils and is distinct to that for the SC3 soils (Figure 6). This

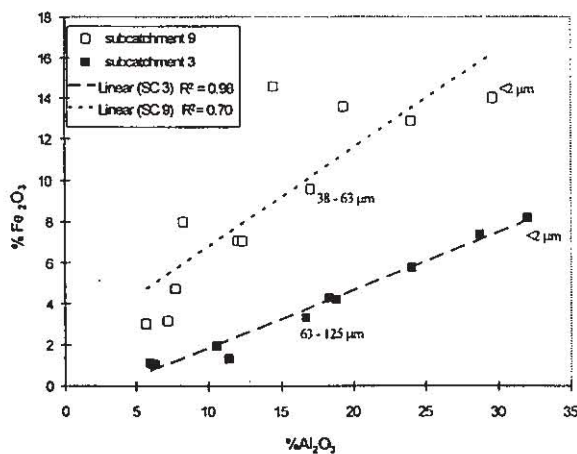


Figure 5. Relationship between Fe_2O_3 and Al_2O_3 for particle size data for the soils of SC3 and SC9

suggests that we should be able to use the combination of the fields defined by the bulk soils and the correlations between these parameters in the different particle size fractions to distinguish sediments derived from the two soils.

3.2.2 Sediments:

SiO₂ and Al₂O₃:

The SiO_2 and Al_2O_3 data from the sediment collected from the weirs on the Tarago River (which drain granite) are also plotted in Figure 2. They are consistent with the regression fitted through the soils data collected from the granite site indicating that they contain the same mineral suite as the soils formed on the granite. Data from the reservoir samples are also shown in Figure 2. Sample R3 plots between the two regression lines fitted through the soils data from SC3 and SC9 suggesting that if these two subcatchments were the only two sources it would consist of a mix (approximately 50:50) of sediment derived from the two lithologies. The four remaining reservoir sediment samples plot below the trend line defined by the SC9 soils and thus outside the fields of the two subcatchments. This suggests different sources for sediment near the inlet of the Tarago River and sediment further down the reservoir.

Given that the two subcatchments sampled are at the extremities of the catchment and make up only a small percentage of the whole catchment, other more direct sources must be considered. Characterisation of clay mineralogy and major element composition of these closer subcatchments may result in a more accurate identification of source. Nevertheless, it is concluded that with the exception of sample R3, the reservoir sediments are most like the basaltic soils derived from SC9.

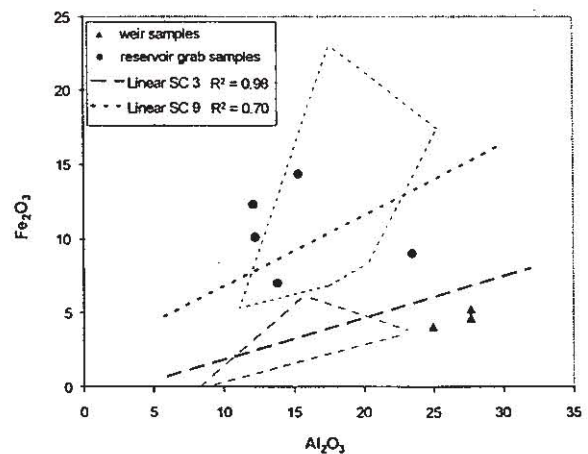


Figure 6. Relationship between Fe_2O_3 and Al_2O_3 for soils and sediment of the Tarago catchment

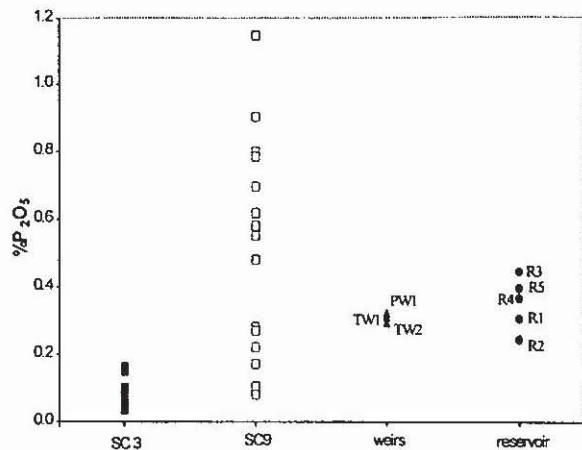


Figure 7. Concentration of P_2O_5 for soils and sediment of the Tarago catchment

Fe_2O_3 and Al_2O_3 :

The Fe_2O_3 and Al_2O_3 data from the weir and reservoir sediment are plotted in Figure 6. The data from the sediment collected from the weirs plots along the regression line defined by the particle size data from the soils of SC3. The concentrations are between those of the soils (which contain the full particle size distribution) and the $<2 \mu m$ clay fraction. This is not surprising; particle size selection during fluvial transport has produced sediment in the weirs with a maximum particle size of $125 \mu m$.

If the granitic soils were a major contributor to the reservoir sediment it is expected that their Fe_2O_3 and Al_2O_3 concentrations would plot close to the regression line defined by the particle size data from SC3 soils. However, the reservoir sediments have Fe_2O_3 and Al_2O_3 contents that are more closely aligned with those of SC9 soils. As before the reservoir sample from near the inlet of the Tarago River (R3) appears to be the only reservoir sample that is a mix of the two sediment sources. This supports the information provided by the $Al_2O_3 - SiO_2$ data. Although the majority of the reservoir samples (R1, R2, R4 and R5) are more closely aligned with the soils of SC9 it is important to note that not all possible sources have been characterised.

Phosphorus:

One of the objectives of this study is to identify the source of phosphorus (P) in the reservoir. The concentrations of P_2O_5 in the soils and sediments of the Tarago catchment are plotted in Figure 7.

The granitic soils of SC3 have a narrow distribution of P_2O_5 concentrations whereas that of the basaltic soils of SC9 is much broader. The concentrations in

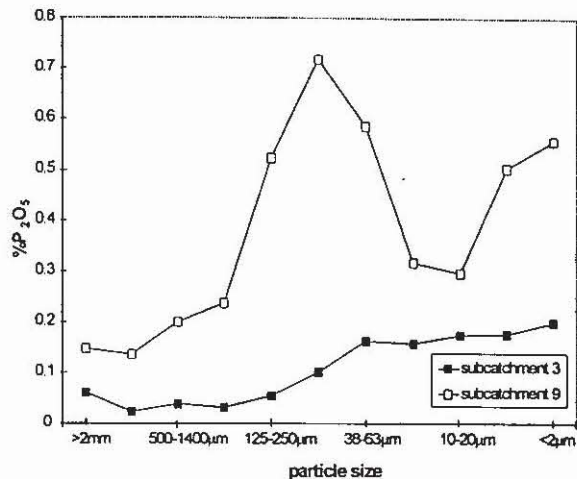


Figure 8. Concentration of P_2O_5 against particle size for the soils of SC3 and SC9.

the SC3 soils are also considerably lower than those of the SC9 soils.

Sediment from the weirs (TW1, TW2 and PW1) and reservoir (R1-R5) have similar P_2O_5 concentrations. The reservoir sediment samples have P_2O_5 concentrations that fall within the range of concentrations found in the soils of SC9. This is consistent with the $Al_2O_3 - SiO_2$ and $Fe_2O_3 - Al_2O_3$ data, which suggested that the reservoir sediment is derived from basaltic soils such as those found in SC9.

Sediment from the weirs is derived from granitic soils similar to those found in SC3 and yet the P_2O_5 concentration is three times higher in the weir sediment than in the soils. Sediment samples from the weirs have a maximum particle size of $125 \mu m$ and the soils of SC3 show an almost monotonic increase in P_2O_5 content with decreasing particle size (Figure 8). At least in part, the higher concentration in the weir sediments could arise from particle size sorting during fluvial transport.

4. CONCLUSIONS

The major element signature of the two subcatchments based on different lithologies have been shown to be distinct. The signature of the sediment from the two weirs in the granite side of the catchment is consistent with that of the soils in the granite subcatchment. The sediments from the body of the reservoir have concentrations more similar to those in the basalt soils although the sample from the upper end of the impoundment appears to be made up of both granitic and basaltic sediment. The clay mineralogy and the phosphorus concentrations are consistent with these observations.

It is concluded that it is practical to use major element geochemistry to distinguish the sources of sediment and particulate phosphorus in the Tarago Reservoir. The next phase of this study will concentrate on a more complete description of the soils based on the two lithologies.

5. ACKNOWLEDGMENTS:

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