THE CONTRIBUTION OF MINERAL WEATHERING TO STREAM SALINITY IN THE BOOROWA RIVER, NEW SOUTH WALES.

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INTRODUCTION

Dryland salinity is a major environmental problem in the upland catchments of the Murray-Darling Basin in south-eastern Australia. Salinity can have adverse impacts on water quality, resulting in loss of biodiversity, degradation of soil structure, loss of agricultural productivity and damage to infrastructure. A study of the contribution of mineral weathering to stream salinity was undertaken in the Boorowa River catchment, in central New South Wales (Figure 1), an upland catchment of the River Murray, during the period August 2003 to January 2004.

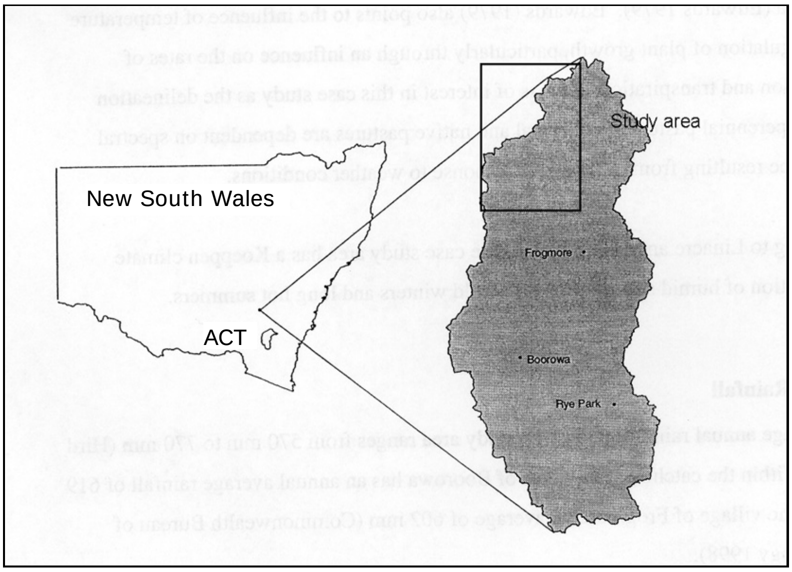

Figure 1: Location of the Boorowa River catchment with the study area indicated.

In previous studies, atmospheric salt deposition had been assumed to be the major source of salt accumulation in the Boorowa landscape (Butler 1956, Chartres 1982, Evans 1998). However, the relationship between the regolith materials, particularly their formation by weathering, and the salt load in the creeks and rivers in the catchment is currently not well understood. The Woolpack Creek and the Breakfast Creek sub-catchments of the Boorowa River catchment were chosen for this study because of the contrasting lithology between, and within, the two sub-catchments (Figure 2).

GEOLOGY AND GEOMORPHOLOGY

The Boorowa River catchment is located within the Lachlan Fold Belt (LFB) in southeastern New South Wales. The geology of the LFB is associated with felsic and mafic volcanism, volcanogenic mineralisation and polyphase deformation, faulting and foliation during the Palaeozoic (Cas 1983, Scheibner & Basden 1995). The lithology of the Boorowa River catchment comprises Ordovician Kenyu metasediments and volcanics, Silurian Douro felsic volcanics and Silurian-Devonian Wyangala granites within the two sub-catchments.

The Kenyu Formation is the oldest formation in the catchment and comprises Ordovician metasediments (sandstones, shale, siltstone, interbedded limestone) and volcanics (andesitic lavas and tuffs). The sediments were deposited in a submarine setting on the continental shelf of eastern Australia during the Ordovician and were subsequently altered by metamorphic and deformational events. Mineralisation consisting of copper-lead-zinc-silver sulphide deposits and tin, tungsten and gold deposits in eastern Australia is associated with granite intrusion and related felsic and mafic volcanism of the Benambran Orogeny during the Late Ordovician (Cas 1983, BMR 1992).

The Kenyu Formation is overlain by the Douro volcanics, comprising felsic basalt and intermediate rocks (dacite, andesite, and andesitic tuffs and ignimbrites), emplaced during the Middle Silurian (Cas 1983, Scheibner & Basden 1995). The Douro volcanics comprises the parent material of the Woolpack Creek sub-catchment and the parent material of the western part of the Breakfast Creek sub-catchment included in this

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study. The Kenyu metasediments and volcanics comprises the parent material of the eastern part of the Breakfast Creek sub-catchment included in this study (Figure 2).

Woolpack Creek sub-catchment (Douro volcanics)
Woolpack Creek is a tributary of Narrallen Creek and is approximately 6 km in length. The topography of the upper reaches is characterised by moderate slopes with outcrops of highly weathered felsic and intermediate volcanics. Woolpack Creek flows from a height of 600 m in the upper slopes to 470 m at the confluence with Narrallen Creek. In the lower slopes extensive bank erosion and incision of the creek into the regolith were evident. There is an extensive scald site in the lower slopes at site WPK7 (Figure 2) and the regolith samples analyzed in this study were collected from this part of the sub-catchment.

Breakfast Creek sub-catchment (Kenyu metasediments and volcanics, Douro volcanics)
Breakfast Creek and Godfrey's Creek are the two main tributaries of the Breakfast Creek sub-catchment (Figure 2). Godfrey's Creek flows north-east through the Douro volcanics and then the Kenyu metasediments and volcanics in the western part of the sub-catchment where it discharges into Breakfast Creek on the lower slopes (Figure 2). There is scalding and die-back of trees along the course of the creek in the lower slopes between sites BRK4 and BRK5 (Figure 2).

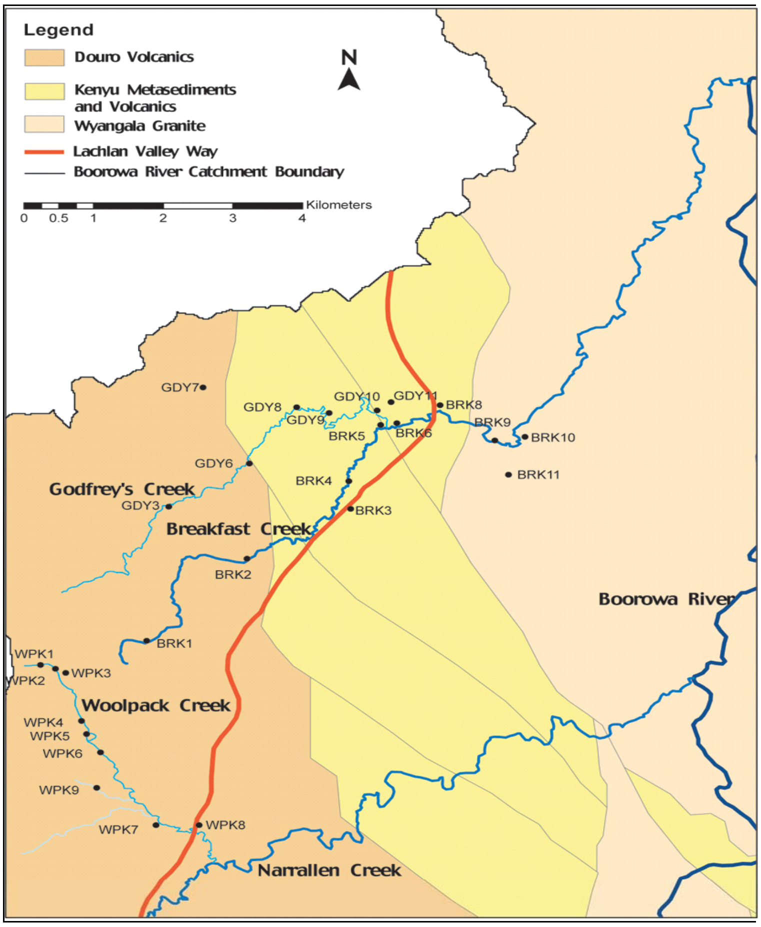

Figure 2: Map of study area showing study sites and basic geology.

METHODS

Water chemistry

Stream water samples were collected from Woolpack Creek and Breakfast Creek/Godfrey's Creek in October 2003 and January 2004 to determine any seasonal contrast in stream water chemistry. The October sample was collected after several days of heavy rainfall, and the January sample after two days of lighter rainfall. Groundwater samples were collected from depths of between 3.7 m and 25 m. Water samples were analysed for electrical conductivity (EC), pH and concentrations of major cations and anions. Rainfall in the catchment averages between ca. 40 and 60 mm/month and is more-or-less evenly distributed throughout the year (BOM 2004).

Regolith chemistry

In the Woolpack Creek sub-catchment, regolith samples were collected from a saline scald site in the lower slopes (site WPK7, Figure 2) where there was evidence of groundwater below the surface. In the Breakfast Creek sub-catchment, samples were collected on a hillslope comprising Kenyu volcanics (site GDY11 Figure 2). There was no groundwater in the upper slopes where this sample was taken

Regolith samples were collected from below the root zone to depths of 6 m using an hydraulic auger in order to isolate any possible influences of parna and evapotranspiration in the soil layers. $EC_{(1:5)}$ samples (mixture of 5 g of soil and 25 ml of distilled water) were allowed to extract overnight. The EC, pH and the concentration of major ions were measured. The bulk chemistry of regolith and parent rock material was measured using X-Ray Fluorescence spectroscopy (XRF). Salts may potentially be stored in the clay layers of the regolith and X-Ray Diffraction (XRD) techniques were used to identify the clay mineralogy of the regolith samples. The relative proportion of 1:1 and 2:1 clays at various depths within the regolith was determined.

RESULTS AND DISCUSSION

Woolpack Creek sub-catchment (Douro volcanics)

In the upper slopes of Woolpack Creek, the EC of the stream water was generally very low (200-500 µS/cm). However, there was a large increase in EC and in the concentrations of major ions at the break of slope (WPK7 Figure 2) associated with the saline scald site (Figures 3a and 3b). This high concentration of salts occurred downstream from where the high-EC groundwater intercepted the stream water, where the creek had incised into the regolith. Two groundwater samples were collected. The EC of one sample was ca. 2300 µS/cm and the other 9300 µS/cm. The major ions in the groundwater were Mg^{2+}, Ca^{2+}, Na^+ and Cl^-, indicating that water-rock interactions and weathering of the parent rock material was the major contributor of ions to the groundwater at this site.

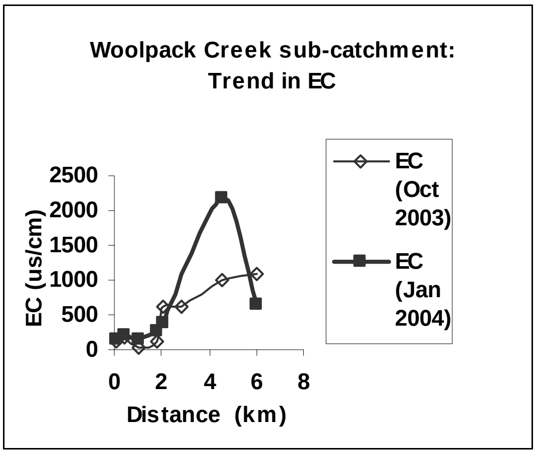

Figure 3a: Trend in EC with distance downstream along Woolpack Creek.

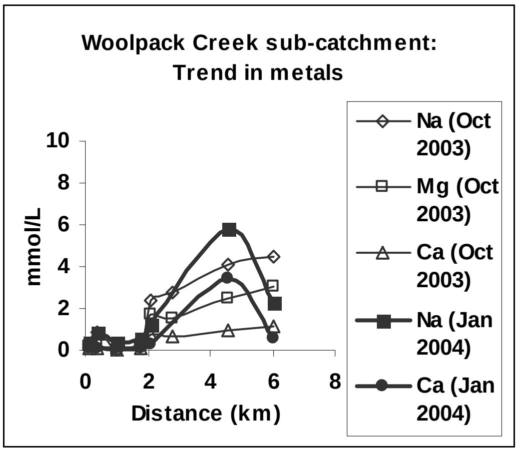

Figure 3b: Trend in major ions with distance downstream along Woolpack Creek

The results for EC$_{1:5}$ soil:water extracts showed a change in composition of easily leachable salts in the regolith. Na^+ and Cl^- ions were most abundant in the upper layers, and Mg^{2+}, Ca^{2+} and Cl^- ions dominated the lower layers.

The dominant clay minerals in the Woolpack Creek sub-catchment were kaolinite (1:1 clay) in the surface layers to 100 cm and smectite (2:1 clay) in the lower layers to 370 cm (Table 1a). Smectite has a high cation exchange capacity (CEC) consistent with the increased concentration of Mg^{2+}, Ca^{2+} and Cl^- ions in EC$_{(1:5)}$ soil:water extracts in the lower layers to 370 cm.

Table 1: clay content statistics for: **a.** Woolpack Creek; and, **b.** Breakfast Creek

a. Woolpack Creek – clay content					**b. Breakfast Creek - clay content**				
Depth cm	**Smc %**	**Mica %**	**Kaol %**	**Regolith clay %**	**Depth cm**	**Vrm/Smc %**	**Mica %**	**Kaol %**	**Regolith clay %**
100	31	18	50	50	300	91	5	4	38
200	66	29	6	42	580	52	14	34	38
230	76	21	2	28	130	47	5	48	36
370	86	5	9	25	280	30	46	24	40

The results of stream water, groundwater and regolith geochemistry suggest a seasonal influence in the release of salts into Woolpack Creek—Mg^{2+}, Ca^{2+} and Cl^- ions were released into stream water during high rainfall periods in winter/spring (October 2003), and Na^+ and Cl^- ions were released into stream water from surface run-off during drier periods in summer (January 2004) (Figures 3a and 3b).

Breakfast Creek sub-catchment (Kenyu Formation and Douro volcanics)

In the upper slopes of Breakfast Creek, EC of the stream water were generally very low, but increased significantly in the lower slopes (Figures 4a and 4b) between sites BRK4 and BRK5 (Figure 2). The major ions in stream water were Na^+, Ca^{2+} and Cl^- in both spring and summer. Two groundwater samples were collected in this area and had a much higher EC (ca. 2200 µS/cm) and a different ionic composition (Ca^{2+}, Mg^{2+}, Na^+ and Cl^- ions) than the stream water.

The $EC_{1:5}$ soil:water extracts was generally less than 100 µS/cm. The 2:1 clay vermiculite was the dominant clay in the upper layers and the 1:1 clay kaolinite was dominant in the lower layers (Table 1b – two samples presented, one on the hillslope, the second at midslope). Ion exchange processes in 2:1 vermiculiteclay contributes some surface runoff of Na^+ and Cl^- ions to stream water, but kaolinite in the lower layers has a low CEC and low salt storage capacity. Although clays are abundant in the regolith here, the clay size and clay composition limits the capacity of the regolith to store salts.

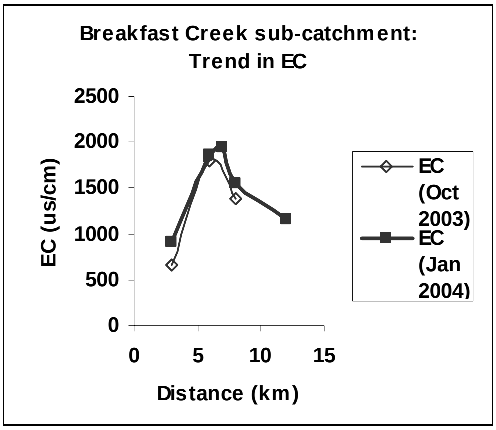

Figure 4a: Trend in EC with distance downstreamalong Breakfast Creek

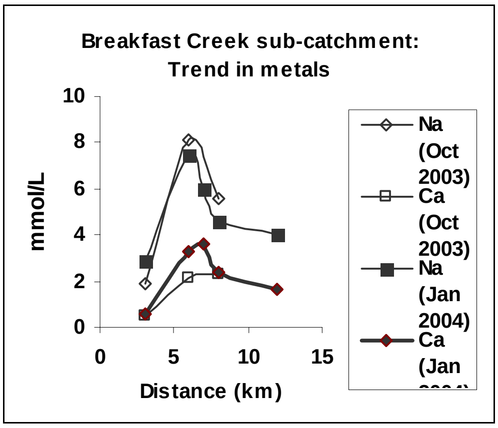

Figure 4a: Trend in major ions with distance downstream along Breakfast Creek

The contrast between the two sites (Woolpack Creek and Breakfast Creek sub-catchments) in the distribution of clay species between the upper and lower regolith layers reflects the difference in the extent of weathering with depth, reactions of clay minerals with ions in groundwater and the difference in physical versus chemical weathering along the hillslope. At Woolpack Creek, the upper part of the regolith is more extensively weathered, leaving a clay mineral assemblage enriched in kaolinite. The lower part of the regolith is enriched in more complex clay minerals, which is due to the less intense leaching and interactions between clays and groundwater. At Breakfast Creek, smectite and vermiculite are more abundant upslope compared predominance of more kaolinite and mica downslope. This is due to relatively more intense physical weathering and transport of regolith material upslope compared to more extensive chemical weathering of regolith material that accumulates downslope .

SUMMARY AND CONCLUSIONS

In the Woolpack Creek sub-catchment (Douro volcanics), the results of the surface water chemistry show a *seasonal* contrast in the concentration of salts in the stream water. In winter/spring there was high EC and higher concentrations of Mg^{2+}, Ca^{2+} and Cl^- ions in the stream water in the lower slopes reflecting groundwater input. In summer, there were higher concentrations of Na^+ and Cl^- ions in the stream water. Stream water data is consistent with the regolith data which shows a concentration of Mg^{2+}, Ca^{2+} and Cl^- ions in the lower layers (reflecting groundwater input to stream water) and Na^+ and Cl^- ions in the upper layers (reflecting surface runoff in summer). The clay mineralogy confirmed the dominance of smectite (2:1 clay) in the lower layers. The high-CEC smectite (2:1) clay can store salts at depth in the regolith and release salts into the stream water during high groundwater flows in winter and spring. Salinity in the Woolpack Creek sub-catchment can be characterised by storage/release (salts stored in 2:1 clays) and mixing (groundwater intercepting stream water).

In the Breakfast Creek sub-catchment (Kenyu Formation and Douro volcanics) , there was no seasonal contrast in the surface water chemistry (Na^+, Ca^{2+} and Cl^- ions dominant). The $EC_{(1:5)}$ of the regolith pore water was low and Na^+ and Cl^- were the major ions. The dominant clays were smectite/vermiculite grading to kaolinite clay in the lower layers. Given the low EC and the low CEC of the clay species, there was a low salt load in Godfrey's Creek, mainly surface runoff of Na^+ and Cl^- ions into the stream water. This lower salt contributed to the dilution of the higher-EC stream water of Breakfast Creek at the confluence of the two creeks at site BRK6 (Figure 2).

From the evidence collected in this study it was concluded that a major source of salts in the stream water resulted from mineral weathering processes at depth the regolith. Salts in parna deposits in the upper layers of regolith play a role in surface runoff of salts into stream water. The different catchments have a different capacity to store salts in the regolith and the storage/release of these salts was related to the 1:1 and 2:1 clay phases produced by weathering resulting from water-rock interactions.

REFERENCES

BMR 1992. *Australia: Evolution of a Continent*. Bureau of Mineral Resources, Canberra, 96 pp.
BOM 2004. Bureau of Meteorology. http://bom.gov.au/.
BUTLER B.E. 1956. Parna – an aeolian clay. *Australian Journal of Science* **18**, 145-151.
CAS R. 1983. A Review of the Palaeogeographic and Tectonic Development of the Palaeozoic Lachlan Fold Belt of Southeastern Australia. *Geological Society of Australia Special Publication* **10**, 3-104.
CHARTRES C.J. 1982. *Quaternary dust mantle soils in the Barrier Range, N.S.W., In:* WASSON R.J. ed. *Quaternary Dust Mantles of China, New Zealand and Australia. Workshop proceedings, Australian National University*, pp. 153-160.
EVANS W.R. 1994. Regional Salt Balances and Implications for Dryland Salinity Management, *Water Down Under '94 Symposium, 21-25 November 1994, Adelaide*, pp. 349-354.
EVANS W.R. 1998. What does Boorowa tell us? Salt stores and groundwater dynamics in a dryland salinity environment. *In:* WEAVER T.R. & LAWRENCE C.R. eds. *Groundwater: sustainable solutions. Proceedings of the IAH International Groundwater Conference, University of Melbourne, 8-13 February 1998*, pp. 267-274.
SCHEIBNER E. & BASDEN H. 1996. Geology of New South Wales – Synthesis. Volume 1 Structural Framework. *Geological Survey of New South Wales* **Memoir 13(1)**, 295 pp.