# ORIGIN AND ACCUMULATION OF SALTS IN THE REGOLITH: BLAND BASIN, NSW

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#### **INTRODUCTION**

Dryland salinity is a significant environmental concern in arid and semi-arid areas throughout Australia. Salinisation of land and water is the result of physical and chemical processes that increase the concentrations of salts in soil and water (Salama *et al.* 1999). Factors contributing to the development of dryland salinity include climate, topography, geology, hydrology and land use practices. Past studies have focused on understanding the distribution of salinity and to a lesser extent the mechanisms of salinisation, but major unresolved questions and uncertainties still remain pertaining to the origins of salts in deeply weathered landscapes. Previous studies (e.g., Gunn & Richardson 1979, Herczeg *et al.* 2001) have attributed its origin to marine transgression, connate seawater, atmospheric accessions, rock weathering and/or evapotranspiration However, estimating the contribution of these factors in a landscape requires detailed knowledge of past and present geologic, geomorphic, hydraulic and climatic conditions. Unfortunately, for most arid and semi-arid areas of Australia, such information does not exist. Accurately determining the origins of salts and accumulation mechanisms in areas possessing an abundance of scientific data will benefit our understanding of the distribution of salt stores and locations of salt hazard areas throughout Australia.

This study is focused on a well-studied area within the Bland Basin of central New South Wales, in the vicinity of Barmedman Creek (Figure 1). Barmedman Creek drains north/northeast towards Bland Creek, a northward-trending ephemeral creek which terminates at Lake Cowal (Gibson *et al.* 2002). Sedimentation of the Bland Basin occurred during the Cainozoic and consists predominantly of alluvial, colluvial and lacustrine deposits (Gibson *et al.* 2002). The Bland Basin is chosen because it is representative of low-lying, salt-affected landscapes throughout the Murray-Darling Basin, and because it has been well studied. There are abundant geophysical, borehole, pore fluid, groundwater, geochemical and mineralogical data available as a result of previous studies during the GILMORE Project (Phillips *et al.* 2002), plus the existence of production and groundwater monitoring bores provides potential for additional sampling and analyses in targeted areas.

# AIMS

The aims of this study are to investigate the origins of high total dissolved solids (TDS) in pore fluids extracted from low permeability clay-rich sediments and to assess their influences on aquifer groundwater



quality. Furthermore, this project aims to interpret the roles of regolith geochemistry and mineralogy on the chemical composition of pore fluids and groundwater, and assess the influences of various regolith lithologies on the accumulation of salts.

# DATA ACQUISITION

The assembling of the existing data has involved close contact and coordination with the Bureau of Rural Sciences (BRS), Geoscience Australia (GA) and the Department of Infrastructure, Planning and Natural Resources (DIPNR) (formerly DLWC). Of particular value has been the acquisition of the airborne geophysical data associated with the GILMORE study. The geophysical data include: airborne magnetics; airborne electromagnetics (AEM); and gamma-ray spectrometry. GIS spatial data were acquired from GA and DIPNR and include a digital elevation model, topographic map, regolith-landform map and

Figure 1: Location of study area relative to the town of topographic map, regolith-landform map and Barmedman, NSW.

borehole locations. Bore water and pore fluid analytical results and drill log information were obtained from BRS and GA. XRD and XRF data were acquired from Professor Tony Eggleton (ANU).

# AEM CONDUCTIVITY AND LITHOLOGY

Lawrie *et al.* (2002) presented AEM images of the Bland Basin that show variable electrical conductivity in the upper reaches of the Barmedman Creek catchment, and in particular highly conductive material between 20 m and 30m depth. At the same depth, dendritic patterns are apparent, trending from the higher conductivity units toward the northeast. These patterns represent palaeo-drainage channels, which presently act as conduits for the transport of saline groundwater (Lawrie *et al.* 2002).

Lawrie *et al.* (2002) also presented the results of grainsize analyses from numerous boreholes located within the areas of moderate electrical conductivity. The results revealed a large sand-dominated unit between 20 m and 30 m depth. Greater proportions of clay-sized particles are present in materials above and below this sandy unit, resulting in confined/semi-confined aquifer conditions. Boreholes located within areas of high electrical conductivity correspond with clay-dominated sediments and saprolite between 20 m and 30 m depth.

#### PORE FLUID AND GROUNDWATER CHEMISTRY, LITHOLOGY AND MINERALOGY

In this section, the results for one diamond drill core, GDH03, are described followed by a more general description and interpretation of water-regolith interaction in the vicinity of the borehole.

#### **Borehole GDH03**

Two diamond cores were drilled in the vicinity of Barmedman Creek, in the northern area ("Area 1") of the GILMORE project. One of the cores, GDH03, was chosen because it is from an area identified as a probable palaeo-channel on AEM 20-30 m and 30-40 m depth-slice images, and because pore fluid, groundwater and mineralogical data are available. On the present land surface, GDH03 is located in the current drainage channel of Barmedman Creek (Figure 1). Analyses of approximately 80 pore fluid samples from near-surface (0.34 m) to nearly 60 m depth reveal an increase in TDS to a depth of 11 m followed by a slight decreasing trend at greater depths (Figure 2). This trend in pore fluid TDS values can be attributed to changes in the physical properties of sediments and/or proximity of the confined aquifers. The increase in TDS at shallow depths correlates well with an increase in clay-sized particles to a depth of approximately 10 m. The gradual decrease in TDS at deeper levels is consistent with increasing grain size to a depth of approximately 20 m. However, a sand-and gravel-dominated unit between 20 m and 30 m marks the onset of a monotonic decrease in TDS values with increasing depth (Figure 2).

Element ratios in pore water correspond to observed changes in mineralogy. Mg/Cl is notably lower in the sandy unit between 20 m and 30 m depth, compared with values in more clay-rich sediments at shallower levels, whereas K/Cl is greater. XRD data indicate the presence of smectite and mica minerals in the clay-rich sediments overlying this sandy unit. The elevated K/Cl and depleted Mg/Cl in the sandy sediments may suggest that there is a downward component of groundwater flow, as the changes in ratios could be the result of cation exchange in the 2:1 clay minerals in the overlying clay-rich sediments. Further mineralogical and geochemical investigations are required to assess the influence of cation exchange and other water-rock interactions on the chemical composition of pore fluids and groundwater.



**Figure 2:** GDH03 pore fluid TDS vs. depth, and groundwater TDS values for boreholes at various depths.

Groundwater sampled from borehole GDH03 at approximately 25 m and 29 m has much lower TDS values than pore fluids sampled at similar depths (Figure 2). The discrepancy may reflect contamination by low TDS waters in the bore rather than a lack of interaction between the pore fluids and groundwater.

### VARIABILITY NEAR GDH03

Boreholes in the vicinity of GDH03 show variability in groundwater composition and lithology at similar depths of 20-30 m, although variations in lithology do not always correlate with fluctuations in groundwater and pore fluid chemistry.

Boreholes GAC14 and GAC16 are located in the relative vicinity of GDH03 (Figure 3) and display groundwater TDS values similar to those of GDH03 pore fluids at 20-30 m depths (Figure 2). Interestingly, GDH03 and GAC14 are dominated by sandy material between 20 m and 30 m, whereas GAC16 at the same depth is dominated by clay-sized material, suggesting that the salinity is not controlled by lithology and mineralogy. However, element ratios are variable between the different boreholes and indicate possible different sources of salt Groundwater from GAC16 has higher Cl/Br and lower SO<sub>4</sub>/Cl compared to that from GAC14 and pore fluids from GDH03. The higher Cl/Br and lower SO<sub>4</sub>/Cl in GAC16 could be the result of halite dissolution.

Groundwater samples from monitoring bores GRB10 and GRB11, also located in the vicinity of GDH03 (Figure 3) and at 20-30 m depth, differ from TDS values from GDH03 (Figure 2). GRB10 is located closer to



**Figure 3:** Digital elevation model displaying monitoring bore and borehole locations.

probable recharge areas than GDH03 and has higher TDS values than all GDH03 pore fluids and groundwater. GRB11 is also closer to probable, but different, recharge areas. However, in contrast to GRB10, GRB11 has TDS values that are more than an order of magnitude lower than all other groundwater and pore fluids sampled over the entire study area. The lithology at 20-30 m depth in both GRB10 and GRB11 is similar, i.e., clay-size dominated saprolite material. GRB11 exhibits notably higher Ca/Cl and lower Cl/Br and SO4/Cl relative to GRB10 groundwater and GDH03 pore fluids at similar depths. Considering the low TDS and ion ratios more consistent with those of local rainfall, GRB11 groundwater most likely represents recharge waters from the adjacent granite hills. Further evidence of the origin of GRB11 groundwater in the adjacent granite hills becomes apparent when considering Na/Br vs. Cl/Br. The ratio reflects an elevated concentration of Na with respect to Cl. This is likely the result of water-rock interactions, specifically the weathering of feldspar from a granitic source rock. A similar Na/Br vs. Cl/Br weathering trend is observed in GDH03 pore fluids between 10 m and 20 m. XRD and XRF results indicate the presence of sodium-bearing minerals in sediments sampled between these depths. These two examples suggest water-rock interactions affect the composition of the groundwater and pore fluids.

# DISCUSSION

Several possible mechanisms could account for the presence of high concentrations of salts in groundwater and pore fluids throughout the study area. A portion of this study aims to address the origins of these salts. One explanation for high TDS pore fluids in the upper portions of the profile is the evapo-transpiration of rainfall and subsequent concentrating of salts in the unsaturated zone. This process has been used to explain the origin of near-surface salts in many semi-arid areas of Australia (e.g., Gunn & Richardson1979, Herczeg *et al.* 2001). However, based on the ion ratios discussed above, it is unlikely that evapo-transpiration alone is responsible for the presence of high TDS pore fluids throughout the Bland Basin. In addition, the origin of salt can also be a result of the depositional history of the Basin, by the incorporation of salt into sediments during deposition.

There are several factors that need to be considered in understanding the origin and nature of salt in the Bland

Basin. Assuming that sedimentation of the Lachlan Valley exceeded that of the Bland Basin, surface waters would have been prevented from reaching the Lachlan River, resulting in the formation of a large swamp or lake (Gibson *et al.* 2002). Due to the seasonal variation in precipitation, large portions of the Basin would have only been under water during the wetter months. Seasonal evaporation of standing water and retreating water levels would have produced localized areas of higher salinity, mostly in the low-lying areas of the Basin. Other factors include fluctuations of the groundwater table due to climatic variations, palaeotopography of the Basin relative to past areas of groundwater discharge and weathering.

# SUMMARY

Borehole GDH03 displays several trends in pore fluid chemistry and lithology at various depth intervals. Pore fluid TDS increases initially with depth, then decreases gradually throughout the remainder of the profile. Element ratios in pore fluids from various depths appear to correlate with changes in lithology and mineralogy, indicating a downward component of groundwater flow. Groundwater sampled from boreholes in the vicinity of GDH03 at similar depths of 20-30 m exhibit variable degrees of salinity. Groundwaters of similar salinity have different chemical compositions, indicating different sources of salts. Variations in regolith mineralogy between boreholes appear to coincide with the chemical composition of groundwater, suggesting water rock interactions as a viable mechanism contributing to groundwater salinity.

The high degree of variability in groundwater quality and the presence of a heterogeneous subsurface architecture highlight the need for further interpretations of existing data and additional sampling and analysis to accurately assess their inter-relationships. Investigations into the possible origins of salts and their rates of accumulation are also needed to assess the influence of past geologic and climatic conditions on present day dryland salinity. The classification and analysis of regolith materials as well as the dating of sediments, pore fluids and groundwater could prove useful tools in unravelling the mystery of how and when the salts accumulated. Interpretation of similarities and differences between pore fluids and groundwater compositions will aid in understanding the evolution of salts in the regolith and their implications on future land and water usage.

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