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Environmental tracers in groundwaters and porewaters to understand groundwater movement through an argillaceous aquitard

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Abstract

Inter-aquifer leakage through an aquitard can be an important component of groundwater flow and can occur by diffuse leakage or via preferential pathways along secondary permeability features. In order to properly characterize inter-aquifer leakage it is desirable to use both porewater from the aquitard in conjunction with a regional investigation of groundwater in the aquifers. The aim of this study was to characterize inter-aquifer leakage through a regionally extensive aquitard between the Great Artesian Basin (GAB) and the deeper Arckaringa Basin of Australia. Chloride concentrations in the aquitard porewater profile indicates that transport through the aquitard is dominated by diffusion, but there is evidence at t least one location for increased interaquifer leakage due to secondary permeability features.

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Keywords: inter-aquifer leakage; aquitard; environmental tracers

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1. Introduction

Aquitards are very important, yet poorly understood components in groundwater flow systems[1]. Regionally extensive aquitards confine and separate aquifers and play an important role in the physical and chemical evolution of groundwater, and can provide water from storage to pumped aquifers[1,2]. Groundwater movement through an aquitard, here referred to as inter-aquifer leakage, can be an important component of groundwater flow, although it is orders of magnitude slower than through aquifers[3]. Quantification of inter-aquifer leakage is important for groundwater resource evaluation and extraction industries including unconventional gas and ore extraction.

Inter-aquifer leakage through a laterally-extensive aquitard can be severely limited but even in the tightest clay or shale aquitard there is always a small amount of diffuse leakage[2]. The inter-aquifer leakage rate through the aquitard can increase if there are secondary permeability features through the aquitard[2,4-6].

To quantify inter-aquifer leakage different techniques are available. Chemical profiles through the aquitard can be used to investigate the transport mechanisms in the aquitard pore water[5,7-10], whereas detection of inter-aquifer leakage through secondary permeability features requires a more regional scale study. Inter-aquifer leakage through secondary permeability features has been identified in some regional groundwater investigations using hydraulic head measurements, environmental tracers and dating tracers in aquifers[11-15].

Several authors[3] urged the use of and comparison of methods at different scales within the same formation. The aim of this study was to investigate inter-aquifer leakage through a regionally extensive aquitard between the Great Artesian Basin (GAB) and the Arckaringa Basin.

2. Study area

This study investigated inter-aquifer leakage between the GAB and Arckaringa Basin in the central to far north region of South Australia (Fig. 1, inset). The GAB comprises Jurassic to Cretaceous sediments that overly the Arckaringa Basin which is a Late Carboniferous to Early Permian sedimentary basin. The main aquifer unit in the GAB is the J-K aquifer and in the study area the main aquifer in the Arckaringa Basin is the Boorthanna Formation (Figure 1a). The J-K aquifer and Boorthanna Formation are separated by a mudstone, siltstone and shale aquitard, known as the Stuart Range Formation (Figure 1b).

3. Methods

To investigate inter-aquifer leakage in between the GAB and Arckaringa Basin regional groundwater samples as well as samples from the aquitard were collected. A core through the aquitard was drilled and aquitard samples collected for environmental tracer analysis[10]. Regional groundwater samples were analysed for various environmental tracers and isotopes including major elements, stable isotopes of water, ^{14}C, ^{36}Cl, $^{87}Sr/^{86}Sr$, uranium isotopes, as well as noble gases.

4. Results and discussion

The chloride concentrations in the aquitard porewater profile are shown in Figure 2. Modelling the profile using the one-dimensional advective-dispersive equation showed that the dominant transport through the aquitard is diffusion. The regional groundwater samples show evidence of inter-aquifer leakage through secondary permeability features in the Stuart Range Formation in the center of the basin. This inter-aquifer leakage has been identified by overlap in Sr and stable water isotope values, chloride concentrations as well as other hydrochemical evidence of mixing with shallower groundwater with shorter residence times. Further evidence is provided by head data which showed a slight draw-down in the upper aquifer during pumping in the lower aquifer.

The results show that flow through the aquitard is dominated by diffusion; there is at least one location with increased inter-aquifer leakage due to secondary permeability features. These results are similar to other studies which have found inter-aquifer leakage through preferential pathways through aquitards[11,15].

5. Conclusions

These results show that diffusion, although dominant is not the only flow mechanism through regional scale aquitards, but secondary permeability features such as fractures and discontinuities can contribute to inter-aquifer leakage. Although cross formational flow is not regionally extensive, it may have a disproportionate impact on water flow and water quality.

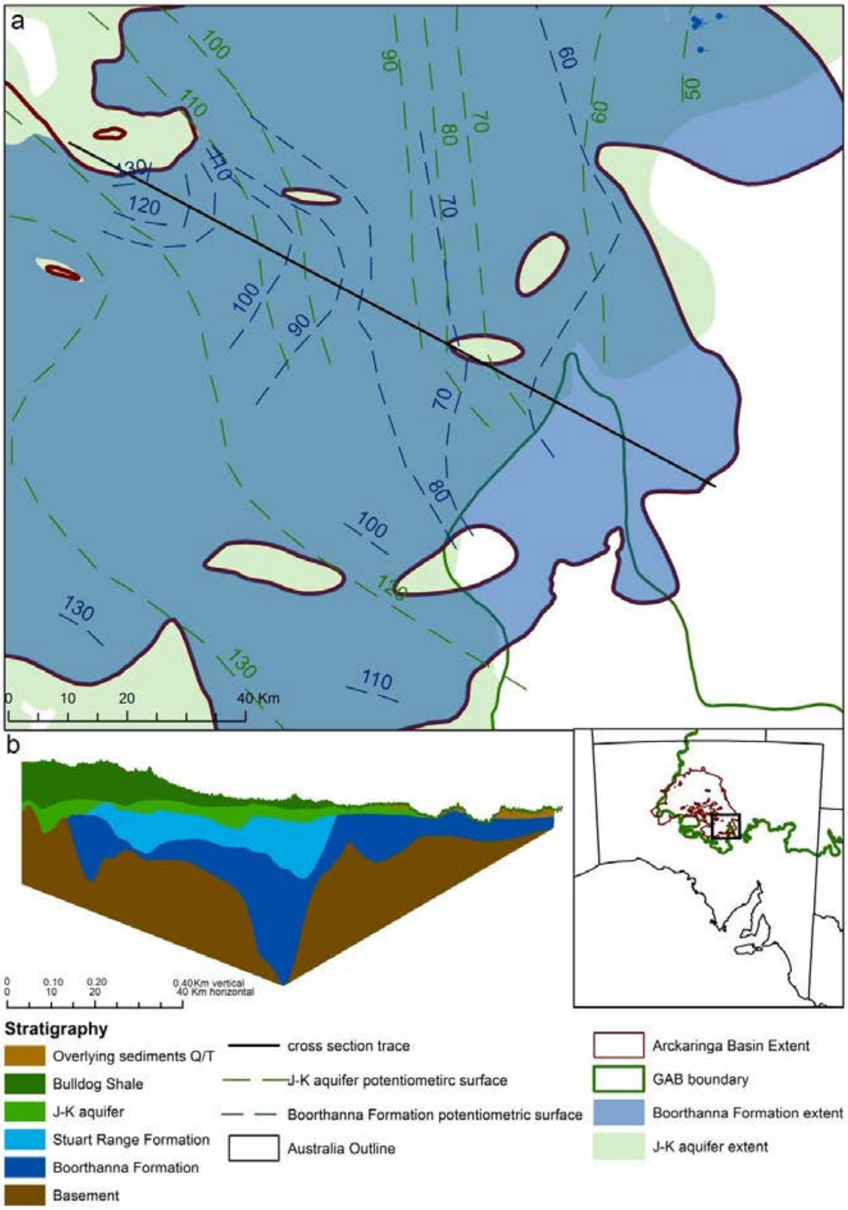

Fig. 1. (a) Map showing upper aquifer extent in green and the density corrected potentiometric surface in green dashed lines. The lower aquifer extent is shown in blue with the density corrected potentiometric surface in blue dashed lines. Cross-section through the study area is indicated with a solid black line (b) stratigraphy of hydrogeological cross-section.

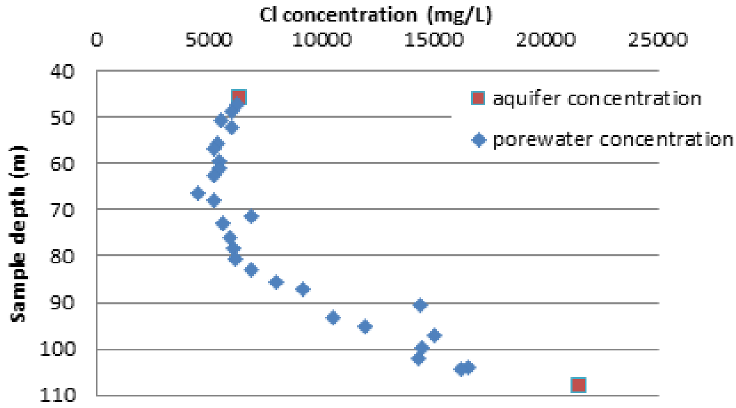

Fig. 2. Chloride concentration through the aquitard.

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