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Groundwater flow and geochemical evolution in the Central Flinders Ranges, South Australia

Alaa Ahmed [a,b,*], Ian Clark [a]

[a] Natural & Built Environments Research Centre, School of Natural and Built Environments, University of South Australia, Mawson Lakes, Adelaide, South Australia 5095, Australia
[b] Geology Department, Division of Water Resource, Desert Research Center, Mathaf El Matariya Street, Cairo 11753, Egypt

HIGHLIGHTS

- The groundwater flow and evolution were studied.
- Hydrogeological and hydrochemical methods were integrated successfully to improve and understand the hydrogeologic setting.
- The results confirmed recharge by rainfall infiltration as the main source of water.
- The conceptual model for recharge and flow is developed.

GRAPHICAL ABSTRACT

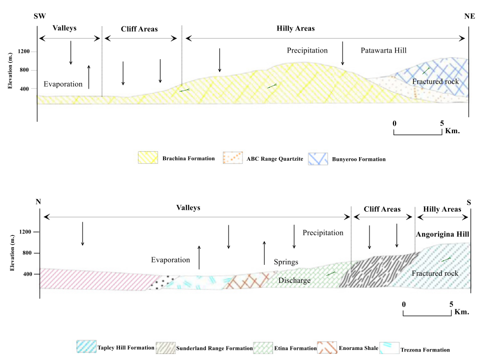

Fig. 1 Conceptual diagram of groundwater flow and evolution in the Oratunga Area

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ABSTRACT

The chemical characteristics of water in the Oratunga Area, Central Flinders Ranges, South Australia have been used to evaluate and determine the processes controlling water chemistry in addition to the sources of ions. The isotopic analysis results show that the groundwater is mainly meteoric. Based on the rock and water chemistry, ionic ratios, hydrochemical facies and saturation indices, the chemical evolution has been studied. The chemistry of groundwater revealed two types of water. Thus, in high topographic areas, low TDS, bicarbonate and mixed water types are dominated and support a rapid and direct recharge. While in the low topographic areas, high TDS and chloride compositions are the most common attributed to the accumulation of ions and groundwater evolution. Analysis of the ion concentration, head data and saturation indices shows a compositional trend that can be studied as an evolutionary system. The ionic ratios and hydrogeochemical modelling using NETPATH was used to quantify and verify the different hydrochemical processes. The resulting data shows that calcite dissolution/precipitation and cation exchange reactions are the major processes affecting groundwater chemical evolution of the groundwater in the basin. This study has provided a basis for a better understanding of the hydrogeologic setting in areas of a little data.

1. Introduction

In arid and semi-arid areas, the scarcity and uncertainty of surface water supply makes groundwater an important part of the total water resource, and plays a useful role as water supply for drinking and

* Corresponding author at: Natural & Built Environments Research Centre, University of South Australia, H2-29, Mawson Lakes campus, Adelaide, SA 5095, Australia.
E-mail address: alaa.ahmed_ismail@mymail.unisa.edu.au (A. Ahmed).

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irrigation (Tsujimura et al., 2007; Keesari et al., 2014). In recent few years, use of groundwater resources has increased remarkably due to drought, the rapid growing of the worldwide economy, and an increase in the worldwide population (Llamas and Martínez-Santos, 2005). The over-use of groundwater has caused many severe problems such as salinization of groundwater, desertification, land salinization, and degeneration of vegetation (Ahmed et al., 2013; Lapworth et al., 2013). Therefore, the sustainable management of water and other environmental resources become an urgent issue worldwide.

Understanding the dynamics of the hydrogeological systems and identifying the hydrogeochemical evolution processes is required for the success of sustainable management experiences (Sophocleous, 2010; Eissa et al., 2014; Brkić et al., 2016). Along the flow-paths within the groundwater systems, the hydrochemical processes affecting the groundwater composition are different; dissolution dominates in the recharge area, ion exchange during the flow, while evaporation, precipitation and ion exchange dominate the discharge area in controlling groundwater chemistry (Tóth, 1999; Adams et al., 2001).

For arid regions, where evaporation dominates precipitation, the hydrogeochemical indicators have been effectively used for tracing the recharge sources and for quantifying the relative evaporation (Gárfias et al., 2010; Herczeg and Leaney, 2011; He et al., 2015; Wang et al., 2015). It has often been used to study the interactions of waters with rocks or sediments and to provide insights into aquifer heterogeneity and connectivity as well as the physical and chemical processes controlling water chemistry (Cartwright and Weaver, 2005; Wells and Price, 2015). In addition, it has been successfully used with isotopes as effective and economic tools in understanding the recharge and discharge of aquifer systems (Cartwright et al., 2006; Dogramaci et al., 2012). Geochemical modelling is used to quantify the geochemical reactions within groundwater systems (Hidalgo and Cruz-Sanjulián, 2001; Londoño et al., 2008; Eissa et al., 2013). The quantitative assessment of reactions in groundwater can be approached using the standard geochemical code, NETPATH-WIN (El-Kadi et al., 2011). Most of these studies focused on areas of a large amount of data however, it remains unclear that whether it is feasible to use the available data to develop a reasonable model on which a sustainability plan for groundwater management can be developed.

In the Oratunga Area (Fig. 1), groundwater is the primary source for fresh water and plays a significant role in occupation and settlement. The region is dependent groundwater stored in fractured rock aquifers (Clark and Brake, 2009). Although the geology and stratigraphy of the bedrock have been studied in some detail (Preiss, 2000; Giddings et al., 2009; Backé et al., 2010; Fromhold and Wallace, 2012), little or nothing is known about the characteristics of groundwater. Therefore, the main objective of this research is to evaluate the dynamics of the groundwater in a limited data area in the Central Flinders Ranges, South Australia; the other aim is to investigate the presence of geochemical processes which would support the existence of different hydrodynamic conditions within the study area. All together directly affect the sustainable management of the water resources for this area.

2. Study area

The Oratunga Area is located in the Central Flinders Ranges, South Australia (Fig. 1). It is situated about 79 km. Southwest of Leigh Creek and 210 km north-east of Port Augusta. It is considered the topographically semi-closed basin. The study area includes about 341 km^2 in Central Flinders Ranges (Fig. 1). The central part has a relatively flat while the marginal areas are hilly and/or mountainous terrains.

The climate of the Flinders Ranges is described by (Schwerdtfeger and Curran, 1996) as arid to semi-arid. The winter rains are prolonged and gentle under low clouds from westerly air masses, while summer rains are brief, and intensely affected by northerly air masses (Schwerdtfeger and Curran, 1996). The average annual rainfall is 300 mm/year, and the mean monthly temperature varies from 16 °C (July) to 35 °C (January). In general, the slow and prolonged rainfall, cool to cold temperature and low

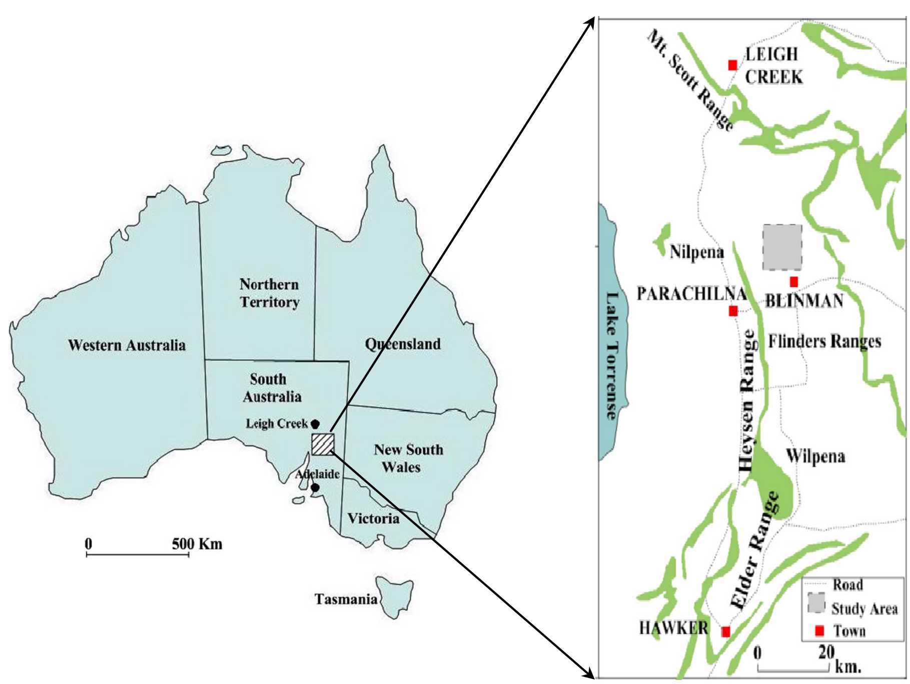

Fig. 1. Location map of the Oratunga Area in the Central Flinders Ranges.