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ScienceDirect
Chemical Geology 246 (2007) 107–123
CHEMICAL GEOLOGY INCLUDING ISOTOPE GEOSCIENCE
www.elsevier.com/locate/chemgeo

Controls on $^{87}Sr/^{86}Sr$ ratios of groundwater in silicate-dominated aquifers: SE Murray Basin, Australia

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Received 22 March 2007; received in revised form 13 September 2007; accepted 15 September 2007

Editor: D. Rickard

Abstract

$^{87}Sr/^{86}Sr$ ratios of groundwater in the southeast Riverine Province of the Murray Basin, Australia are between 0.7107 and 0.7191. The $^{87}Sr/^{86}Sr$ ratios vary between different subcatchments and generally decline with distance northwards from the basin margins. There are few carbonates in this region, and Sr is primarily derived from silicate minerals. The spatial variation in $^{87}Sr/^{86}Sr$ ratios reflects the distribution of K-rich minerals, such as biotite and K-feldspar in the aquifers. However, major ion chemistry implies that silicate weathering is only a minor process. Sr isotope ratios are most probably controlled by exchange on clays derived from weathering of the silicate minerals. Ion exchange is promoted by the low groundwater flow rates in the Riverine Province and the clay-rich nature of many of the aquifers.

Keywords: Sr isotopes; Groundwater; Isotopic exchange

1. Introduction

Constraining water–rock interaction, evapotranspiration, dissolution and precipitation of minerals, ion-exchange and groundwater mixing is required for understanding and managing hydrogeological systems. $^{87}Sr/^{86}Sr$ ratios of groundwater are important tracers of hydrological processes. The utility of Sr isotopes in hydrogeology is for a number of reasons. Firstly, minerals with which groundwater and surface water interact have a wide and predictable range of $^{87}Sr/^{86}Sr$ ratios. ^{87}Sr is produced by the decay of ^{87}Rb with a half-life of 48.8 Ga (Faure, 1991). Rb readily substitutes for K and to a lesser extent Na in many minerals, while Sr substitutes for Ca. Thus, the $^{87}Sr/^{86}Sr$ ratio of a mineral is governed by its initial $^{87}Sr/^{86}Sr$ ratio, its Rb/Sr ratio, and its age (Faure, 1991; McNutt, 2000). In rocks that are more than a few million years in age, Sr derived from K-rich minerals such as biotite and K-feldspar will have high $^{87}Sr/^{86}Sr$ ratios. Minerals such as plagioclase that have lower K/Ca ratios will contain Sr with moderate $^{87}Sr/^{86}Sr$ ratios, while the Sr in Ca-rich minerals such as calcite or gypsum will have low $^{87}Sr/^{86}Sr$ ratios that remain essentially unchanged over

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0009-2541/$ - see front matter
doi:10.1016/j.chemgeo.2007.09.006

time (Faure, 1991; McNutt, 2000). Secondly, unlike C, O, H, or S isotopes, mineral precipitation and dissolution does not fractionate $^{87}Sr/^{86}Sr$ ratios. Thus, minerals in igneous rocks have initial $^{87}Sr/^{86}Sr$ ratios that are identical to those of the melt from which they crystallised, limestones have initial $^{87}Sr/^{86}Sr$ ratios that are the same as those of the water in which they were formed, as do veins and cements. Finally, the very long half-life of ^{87}Rb compared with typical groundwater residence times of <1 Ma means that there is essentially no change in $^{87}Sr/^{86}Sr$ ratios due to the decay of ^{87}Rb in groundwater.

Commonly, Sr isotopes are used for determining mixing in aquifers between groundwater that has interacted with rocks that have distinct $^{87}Sr/^{86}Sr$ ratios (e.g., carbonates and silicates or young sediments and old radiogenic basement: e.g. Katz and Bullen, 1996; Armstrong et al., 1998; Negrel et al., 2001; Grobe and Machel, 2002; Dogramaci and Herczeg, 2002; Negrel, 2006). In such circumstances, the mixing dominates the Sr geochemistry and controls the $^{87}Sr/^{86}Sr$ ratios. Sr isotopes have also been used in silicate-dominated aquifers to examine mineral dissolution (e.g. Bullen et al., 1996; Harrington and Herczeg, 2003). Here, we discuss the Sr isotope geochemistry of groundwater from the Riverine Province of the southeast Murray Basin, Australia, which is a region dominated by silicate-rich aquifers. These data were

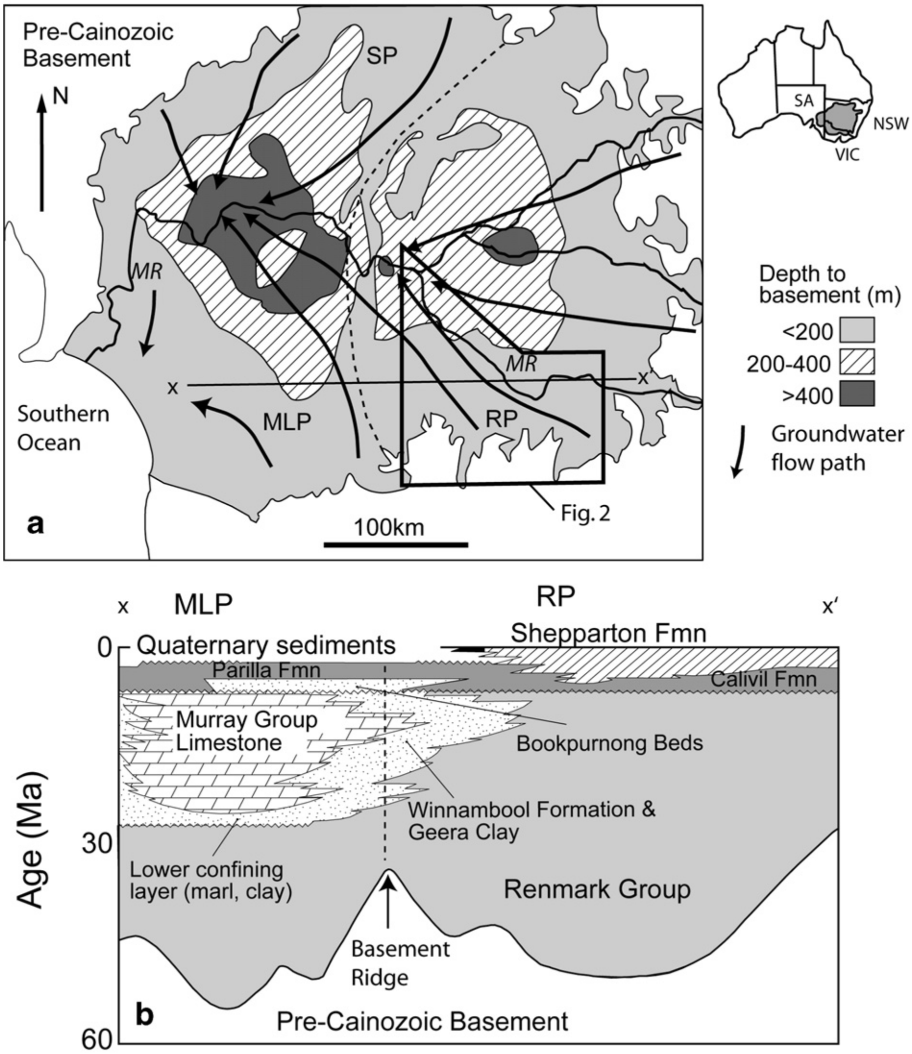

Fig. 1. a. Map of the Murray Basin (after Evans and Kellett, 1989) showing depth to basement, groundwater flow paths (arrowed), and major rivers. MLP = Mallee-Limestone Province, RP = Riverine Province, SP = Scotia Province. NSW = New South Wales, SA = South Australia, Vic = Victoria. Box shows location of Fig. 2. b. Generalised stratigraphic cross-section across the Mallee-Limestone and Riverine Provinces (after Evans and Kellett, 1989) showing major units in the Murray Basin.