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Investigating the Origin and Interaction between Karstic and Alluvial Aquifers in NW of Zagros Mountain Range, Iran, Using Isotopic and Geochemical Tools

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Abstract

Zagros mountain range (ZMR) contains the most karst carbonate formations in Iran. Because of the broad expansion of folded and fractured carbonate rocks, well-developed karstic aquifers occur in NW of ZMR which is reflected in the existence of many karstic springs with large discharge (up to 6 m³/s). These important karstic formations in Paveh (PV), Javanrood (JR), Ravansar (RS) and Sarpol Zahab (PZ) study areas supply water for residents and may be a recharge source for the adjacent alluvial aquifers. Recognizing the recharge areas of these karstic springs and aquifers are very important for protection of water resources. A narrow range of isotopic compositions in JR ($\delta^{18}\text{O}$ values of -7.5 to -7.0‰ and $\delta^2\text{H}$ values of -38 to -35‰) and PV regions ($\delta^{18}\text{O}$ values of -7.5 to -6.3‰ and $\delta^2\text{H}$ values of -40 to -34‰) indicates the same origin for water for springs and rivers in these areas. The wider isotopic range of $\delta^{18}\text{O}$ (-8.1 to -5.6‰) and $\delta^2\text{H}$ (-46 to -26‰) in RS and PZ regions ($\delta^{18}\text{O}$ values of -6.8 to -3.9‰ and $\delta^2\text{H}$ values of -36 to -22‰), indicate the existence of different recharge areas for the aquifers in these areas. PZ is the only study area that has 5 alluvial springs and their isotopic compositions indicate the alluvial aquifer is fed by discharge from the underneath karstic aquifer. The good correlation between altitude and isotopic composition in springs indicates that the altitude of recharge is the main factor controlling the isotopic composition of the water in the study areas.

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1. Introduction

As constituents of the water molecules, ¹⁸O and/or ²H isotopes can be referred as the water cycle’s ‘fingerprints’ to trace the origin of water in the hydrological cycle. Environmental isotopes have been known as effective tools in studying groundwater and hydrological systems¹. These natural tracers can provide information about groundwater origin²; groundwater residence time; groundwater renewability; groundwater–surface water interactions; and recharge areas of springs. The Zagros mountain range (ZMR) contains more than 55.2 % of the total karst carbonate formations in Iran³. Because of the broad expansion of folded and fractured carbonate rocks and the existence of many karstic springs with large amount of discharge water (up to 6 m³/s), well-developed karstic aquifers are found in the NW of ZMR. These karstic formations supply water for residents and are a source of recharge to the adjacent alluvial aquifers. The main objective of the study presented in this paper is to evaluate the origin of water in alluvial and karstic aquifers aiming for a better understanding of the groundwater flow system and the interaction between alluvial and karstic aquifers in selected study areas (Paveh - PV, Javanrood - JR, Ravansar - RS and Sarpol Zahab - PZ – Fig. 1a) using isotopic and geochemical tools. The information obtained in this study will contribute to a better management of the water resources in these regions.

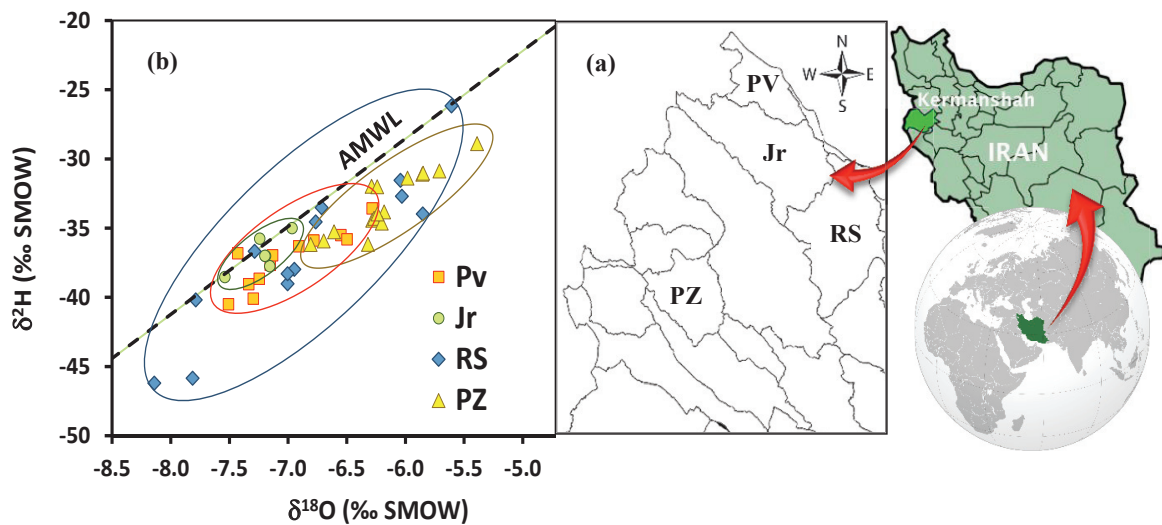


Fig. 1. The locations of Paveh (PV), Javanrood (JR), Ravansar (RS) and Sarpol Zahab (PZ) study areas (a), and isotopic (δ¹⁸O and δ²H) compositions of water in the study areas (b), the local meteoric water line of nearby region, (δ²H = 6.35 δ¹⁸O + 9.56)⁴ was used as a reference line.

2. Sampling and methods

Water samples were collected from precipitation stations, springs, wells and rivers during 2014-2015. Field parameters, T, pH, Eh, EC, and TDS, were measured during sampling. The geochemical analyses included main cations and anions and the isotopic analyses included ¹⁸O and ²H in water, ³⁴S and ¹⁸O in sulfate and ¹³C in dissolved inorganic carbon. The geochemical and isotope analyses were performed in the geochemistry and environmental isotope laboratories of University of Waterloo, respectively. Here we present and discuss ¹⁸O and ²H data in order to characterize water origins in this karstic aquifer system and its interaction with the alluvial aquifers.

3. Results and discussion

3.1. $\delta^{18}\text{O}$ and $\delta^2\text{H}$ data in different study areas

The isotope data, plotted on a $\delta^{18}\text{O}$ vs $\delta^2\text{H}$ diagram showed a wide range in isotopic composition that varied between -8.0‰ and -3.9‰ for $\delta^{18}\text{O}$ and -46.2 and -21.7 for $\delta^2\text{H}$ (Fig.1b). A relative narrow range is observed in $\delta^{18}\text{O}$ values (-7.5 to -7.0‰ and -7.5 to -6.3‰, respectively) and in $\delta^2\text{H}$ (-38 to -35‰ and -40 to -37‰, respectively) for JR and PV areas (Fig. 2). This indicates that the altitudes of the recharge areas of the springs located in these areas are the same. The rivers in the PV area tend to be the more enriched in ^{18}O and ^2H probably due to evaporation along the river course (Fig. 2). The wide range of $\delta^{18}\text{O}$ (-8.1 to -5.6‰) and $\delta^2\text{H}$ (-46 to -26‰) in RS and in PZ (from -6.8 to -3.9‰ and from -36 to -21‰ for $\delta^{18}\text{O}$ and $\delta^2\text{H}$, respectively), indicate the existence of different recharge areas for the aquifers in these areas (Fig. 2). Because of low elevation and warmer area, the ^{18}O and ^2H isotope data for the PZ area are more enriched than that of the RS area. PZ is the only study area that beside karstic springs has 5 alluvial springs as well. Similar isotopic composition for springs discharging from the karstic and alluvial aquifers indicated that the karst aquifer is the source of the recharge to the alluvial aquifer. The more ^{18}O and ^2H enriched water, in the other word the heaviest water in the RS study area are three low flow springs discharging from the Radiolarit formation and they represent local recharge at low elevation probably affected also by evaporation. The most ^{18}O and ^2H depleted water is observed in a deep well (KRWW) drilled in the limestone formations which is used as a water supply for the population in the area. These data suggest a higher elevation of recharge for the deep aquifer. The isotope data suggested the existence of recharge areas at different altitudes in the study areas. This hypothesis will be examined in the next section evaluating the relationship between altitude and isotopic composition for springs.

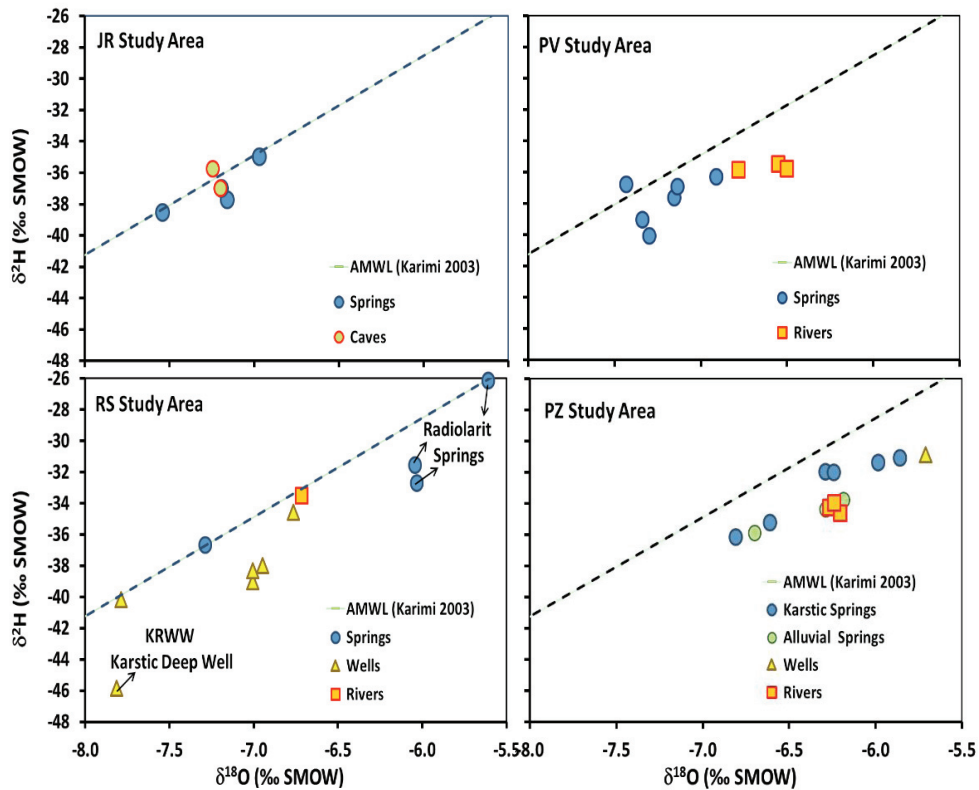


Fig. 2. Isotopic composition ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) of rivers, springs and wells water in PV, JR, RS and PZ study areas.

3.2. Altitude vs. ^{18}O relationship for springs in different study areas

The typical pattern of a trend toward lower $\delta^{18}\text{O}$ values associated with an increase in altitude is observed in these data (Fig. 3). There is one spring which is not part of the general pattern indicating the sampling location for this spring is far from the recharge area. The plot of $\delta^{18}\text{O}$ values vs. altitude yields a best-fit line with a slope of $-0.10\text{‰}/100\text{m}$ with a R^2 of 0.60, which is in the same range for precipitation in Oman and West Africa³. The relationship between altitude and isotopic composition will be reevaluated when the isotope data collected in precipitation stations at different altitudes in the study areas is available.

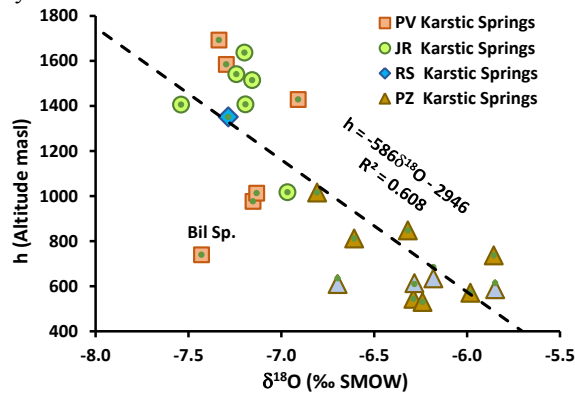


Fig. 3. Altitude vs. $\delta^{18}\text{O}$ for springs from the different study areas.

4. Conclusion

The isotope data (^{18}O and ^2H) indicates that water resources in PV and JR study areas have the same origin and the aquifers in the PZ and RS regions have different recharge areas. The isotope data also showed that the alluvial aquifer in the PZ region is feed by the deeper karstic aquifer. It seems the groundwater flow system and recharge elevations are the main factors controlling the isotope composition of groundwater and surface water resources in the PV, JR, RS and PZ study areas. Recognizing the recharge areas of the karstic springs and of aquifers and also a better understanding of the groundwater flow dynamics in these areas (which have different elevations and different topography) provide vital information for a better management of water resources, which are supplying drinking water for cities and villages in these regions. The interpretation based on the isotope data in water will be later complemented with isotope data collected in sulfate and dissolved inorganic carbon and geochemical analysis in water.

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