Water-rock interaction in the mixed carbonate-evaporite system aquifers, Qatar: Hydrochemistry and isotope geochemistry approaches

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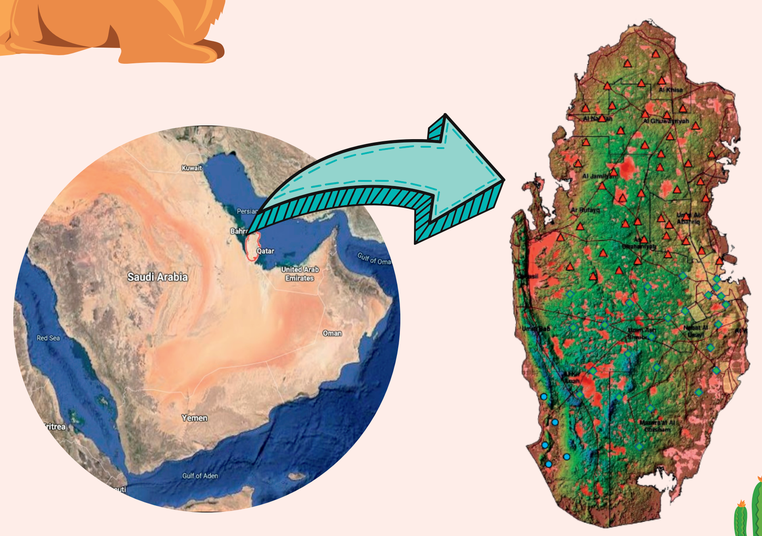
1. STUDY AREA



- Qatar is one of the semi-arid countries in the Arabian peninsula with a limited freshwater supply, due to a very low average annual rainfall (less than 100 mm/year) and a high annual evaporation rate (more than 30 times higher than precipitation).
- Qatar has the largest hydrocarbon reserves in the world, responsible for the highest income per capita in the world, it is the poorest country in the world in freshwater resources.
- Groundwater is an important resource in Qatar, but in terms of consumption, understanding groundwater spatial distribution and groundwater quality can be challenging.

2. RESEARCH OBJECTIVES

- To provide an understanding of the nature of the spatial distribution of the interaction between host rocks, minerals in aquifer and groundwater based on analysis of the concentration of major ions
- To identify diagenetic processes in mix carbonate-evaporite system aquifers from $\delta^{34}S$ and $\delta^{18}O_{sulfate}$ results
- To distinguish water mixing by using $\delta^{2}H$, $\delta^{18}O_{waters}$ $\delta^{34}S$ and $\delta^{18}O_{sulfate}$ data
- To identify the recharge processes, paleoclimate conditions by using $\delta^{2}H$, $\delta^{18}O_{water}$ data
- To identify the sources of sulfate in waters, distinguishing contributions from natural or anthropogenic sources using sulfur isotope ($\delta^{34}S$)

3. APPROACHES

- Major ions Ca^{2+}, Mg^{2+}, K^{+}, SO_4^{2-}, Cl^{-}, HCO_3^{2-}
- Geochemical modeling PHREEQC
- Ions derived from water-rock interaction
- $\delta^{18}O_{water}$ and $\delta^{2}H$
- $\delta^{18}O_{sulfate}$ and $\delta^{34}S$

4. GEOLOGY & HYDROGEOLOGY

The near-surface aquifers of Qatar consist of three formations:

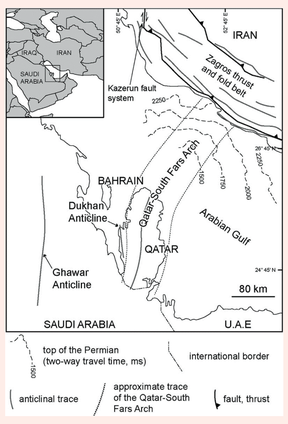
(1) the Paleocene-Lower Eocene Umm er Radhuma Formation (UER),

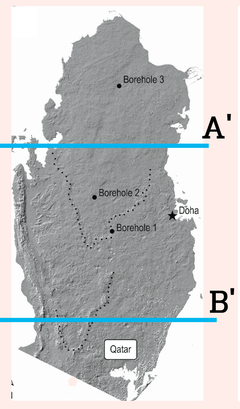
(2) the Lower Eocene Rus Formation, and

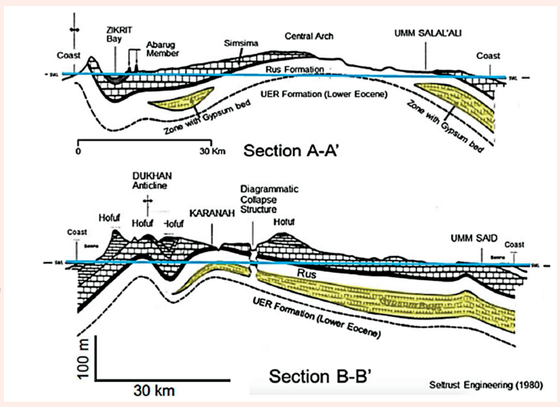
(3) the Middle Eocene Dammam Formation.

- The UER Formation does not outcrop in Qatar but is an important aquifer with a thickness between 100 and 370 m (Eccleston et al. 1981; Boukhary et al. 2011). the UER formation consists of off-white dolomitic limestones underlain by harder vesicular dolomite (Eccleston et al.1981).
- Overlying the UER Formation is the Rus Formation, which is understood to vary in thickness across on shore Qatar between a minimum of 15m in the Dukhan area to a maximum of 122 m in southwestern Qatar (Eccleston et al.1981).
- The Rus Formation is generally considered to have been deposited in shallower marine environments relative to the UER Formation (Eccleston et al. 1981).
- The depositional facies of the Rus Formation varies from north to south across Qatar, being segregated by a V-shaped escarpment apparent in satellite imagery. South of this escarpment, the Rus Formation consists of meter-scale dolomite-gypsum-clay cycles interpreted to represent restricted lagoon to supratidal settings (Abu-Zeid 1991; Al-Saad 2003).
- To the north of the escarpment, the thick gypsum and clay beds are absent, and dolomitic limestone predominates, reflecting normal marine depositional conditions

The Rus Formation and UER Formation are possibly the most important aquifers in terms of storage capacity and extent and underlie the whole of the Qatar peninsula. The Abarug Member of the Dammam Formation mainly in the SW part of Qatar and forms a small aquifer body in this area.



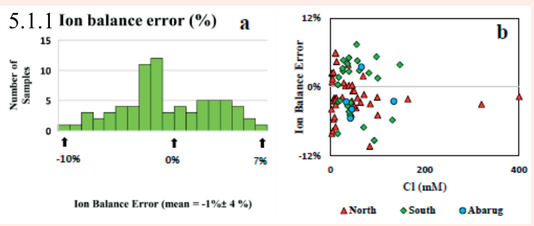




5. METHODOLOGY

• 5.1 Hydrochemistry

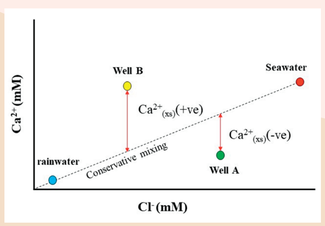
5.1.1 Ion balance error (%)



5.1.2 Ions derived from water-rock interaction

$$(Ca)_{xs} = Ca_{sample} - (Ca_{seawater} \times SEM)$$

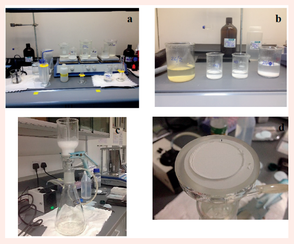
$$SEM = \frac{Cl^-_{sample}}{Cl^-_{seawater}}$$



5.1.3 $SI_{minerals}$ and pCO_2

• 5.2 Isotope geochemistry

5.2.1 Preparation of $BaSO_4$, sulfate-oxygen line and IRMS analyser

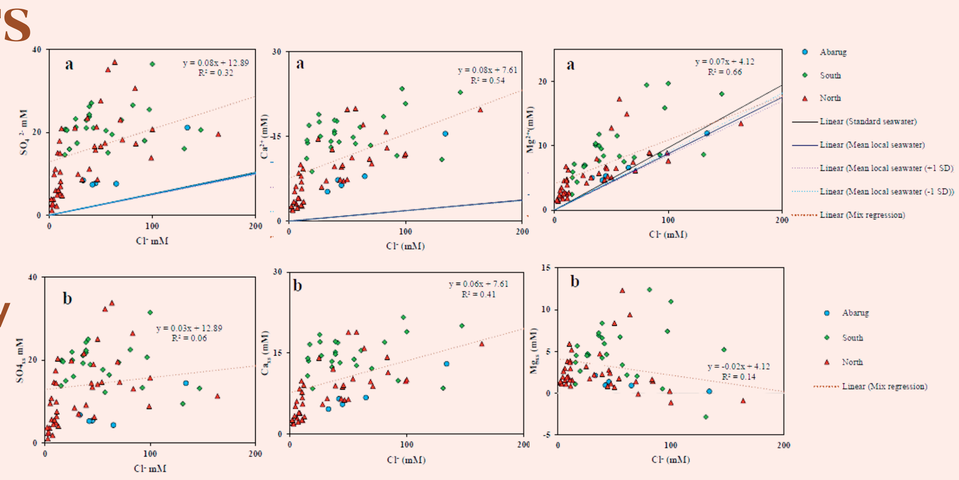


5.2.2 Sulfur isotope measurements

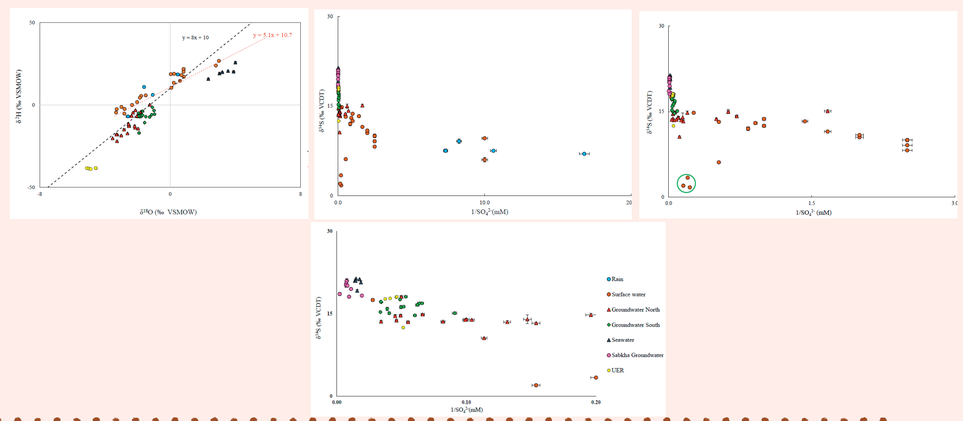
5.2.3 Stable isotope measurements

6. RESULTS

Hydrochemistry

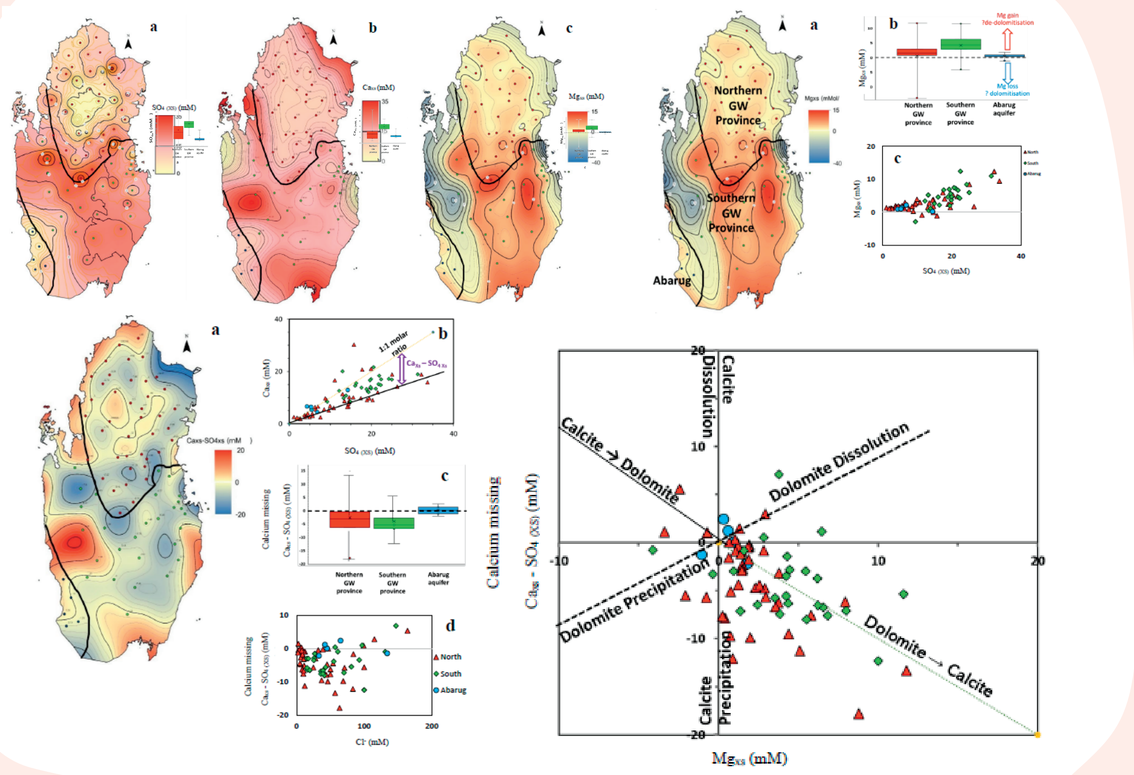


Isotope geochemistry

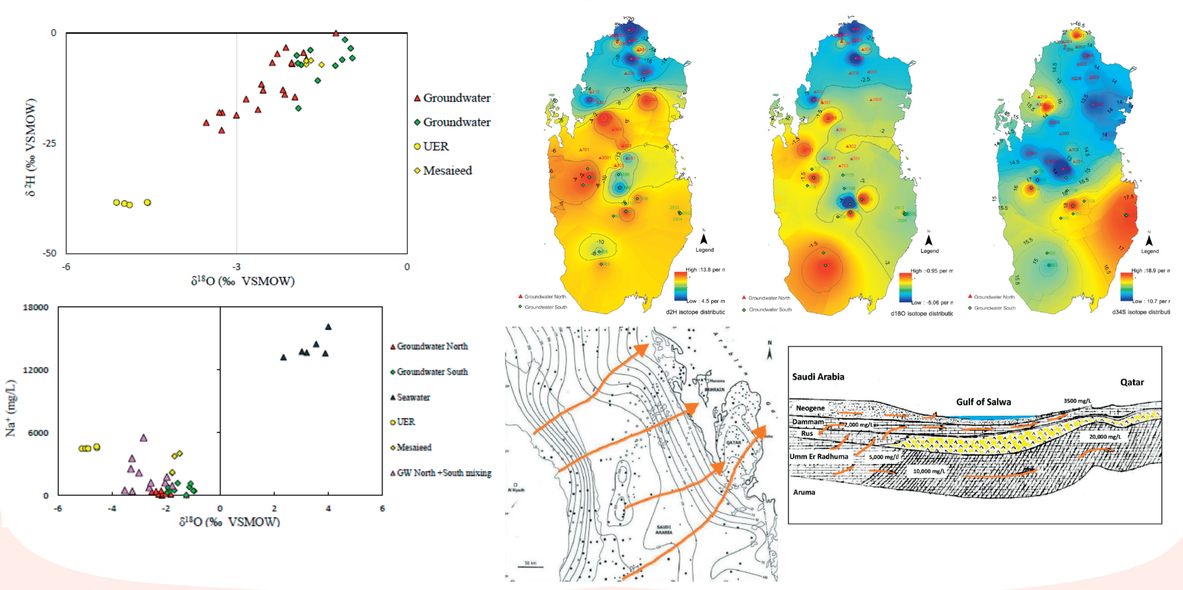


7. DISCUSSION

• Hydrochemistry



• Isotope geochemistry



8. CONCLUSIONS

- Gypsum dissolution is a major process occurring in Qatar which results in the enrichment of calcium and sulfate in the Rus groundwaters
- The enrichment of these ions occurs to a higher degree in the south than in the north
- Additional sulfur isotope measurements of both surface detention water and groundwater support the results from hydrochemical data that the significant spatial differences in sulfate enriched is caused by the major gypsum bed in the Rus Formation
- The dissolution of gypsum is the main process that drives most of the geochemical differences in the mixed carbonate-evaporite aquifer system in Qatar
- Dedolomitisation, dolomite replacement by calcite, also occurs in the Rus aquifer which results in magnesium enrichment in the Rus groundwaters.
- Dedolomitisation process is ultimately driven by gypsum dissolution, which produces calcium ions, and may also be driven by hydrogen sulfide oxidation, which releases hydrogen ions into the groundwater system
- Dedolomitisation process releases CO_2 into the Rus aquifer which results in extremely high pCO_2 in Rus groundwaters
- The sulfate source in southern Rus groundwater is derived from a massive gypsum layer within the south Rus Formation. The main source of sulfate in northern Rus groundwater, where there is no gypsum bed in the Rus Formation, is derived from sulfate in UER groundwater that mixes with northern Rus groundwater.
- Isotope analyses and hydrochemistry confirm that the UER aquifer is leaking upward to the northern Rus aquifer
- Recharge processes have been determined from the stable isotope compositions of water which indicate only direct recharge to groundwater aquifer
- The stable isotope compositions themselves show no evidence of seawater intrusion in Qatar groundwater
- The different paleoclimatic conditions during water recharge into deep aquifers have been preserved in the stable isotope compositions of water which indicate that groundwater was recharged during a colder, more humid climate at ~23ka
- The sulfate source in the Rus groundwater (both northern and southern) are from the dissolution of gypsum dust in the atmosphere and deposited on the surface
- The findings are similar to other studies in the Arabian peninsular, consistent with the main source of sulfate on the surface originating from dust storms which contain particulate sulfate common to the region