

## **Evaluating the geochemistry of Bam salt dome in Hormozgan Province, Iran**

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**ABSTRACT:** Evaluation of the geochemistry and hydrochemical quality of Bam salt dome located in southern Iran, was conducted in this study. Two composite samples from salt units were collected and analysed by XRD and XRF to determine their mineral and elemental compositions. Water samples were also collected from the only spring in the area and analysed for major anions, cations and some toxic elements. The results indicated halite as the major mineral present, while quartz, anhydrite and dolomite were present at minor levels. The presence of anhydrite and dolomite together with quartz had negative effects on edible salt quality. The dominant water type in the area was sodium-chloride. Negligible sulphate and calcium contents may be attributed to anhydrites detected in the geological texture of the study area. According to a Schoeller diagram, the water is not suitable for drinking. Concentrations of toxic metals in the salt sample were significantly higher than those in water samples. Such a result can be viewed as an opportunity to produce edible salts from the evaporation of spring water.

**Key words:** Geochemistry, Hormozgan, Hydrochemistry, Salt dome

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### **INTRODUCTION**

The different origins of saltwater in coastal aquifers have been studied by many researchers worldwide and several reasons for this occurrence have been proposed (Testa and Lugli, 2000; Talbot et al., 2009; Stein, 2001; Closson et al., 2007; Simms and Garven, 2004; Salameh and El-Naser, 2000; Azam, 2008). Fossil seawaters, seawater intrusion as a result of excessive pumping, evaporite dissolution, downward leakage from surface saline water through malfunctioning wells and upward flow from deep brine or saline water are among the most frequent justifications (Pulido-Leboeuf et al., 2003; Vengosh et al., 1999; Yamanaka and Kumagai, 2006; Kim et al., 2003; Talbot and Aftabi, 2004; Holzbecher et al., 2010; Schoenherr et al., 2010).

Being located in a semi-arid area, Iran suffers from water shortage consequences, with an average annual precipitation of less than one third of that of the entire globe (Talbot, 2008; Arian, 2012). Furthermore, the non-integrated distribution of precipitation, both spatially and temporally, is another issue affecting the country in this context. Iran has been identified as one of 27 candidate countries to reach a water crisis by 2025. Both geopogenic (frequent droughts) and anthropogenic (uncontrolled groundwater use) factors have deteriorated the quality and quantity of Iran's aquifers in recent decades; these occurrences have been more severe in the southern parts of the country, where a harsher climate dominates.

A salt dome is a type of structural dome formed when a thick bed of evaporite minerals (mainly salt, or halite) found at depth

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intrudes vertically into surrounding rock strata, forming a diapir (Hogan, 2011; Al-Siyabi, 2005; Appelo and Postma, 2005). Generally, geopogenic sources may adversely affect water bodies' quality, especially when being influenced by anthropogenic factors (Azam, 2007; Nasrabadi et al., 2010; Siemann and Schramm, 2000).

**Study area**

Except for a strip along the Persian Gulf's coastline, Hormozgan Province experiences an arid climate with an annual average precipitation of less than 170 millimetres and a maximum temperature of more than 45°C.

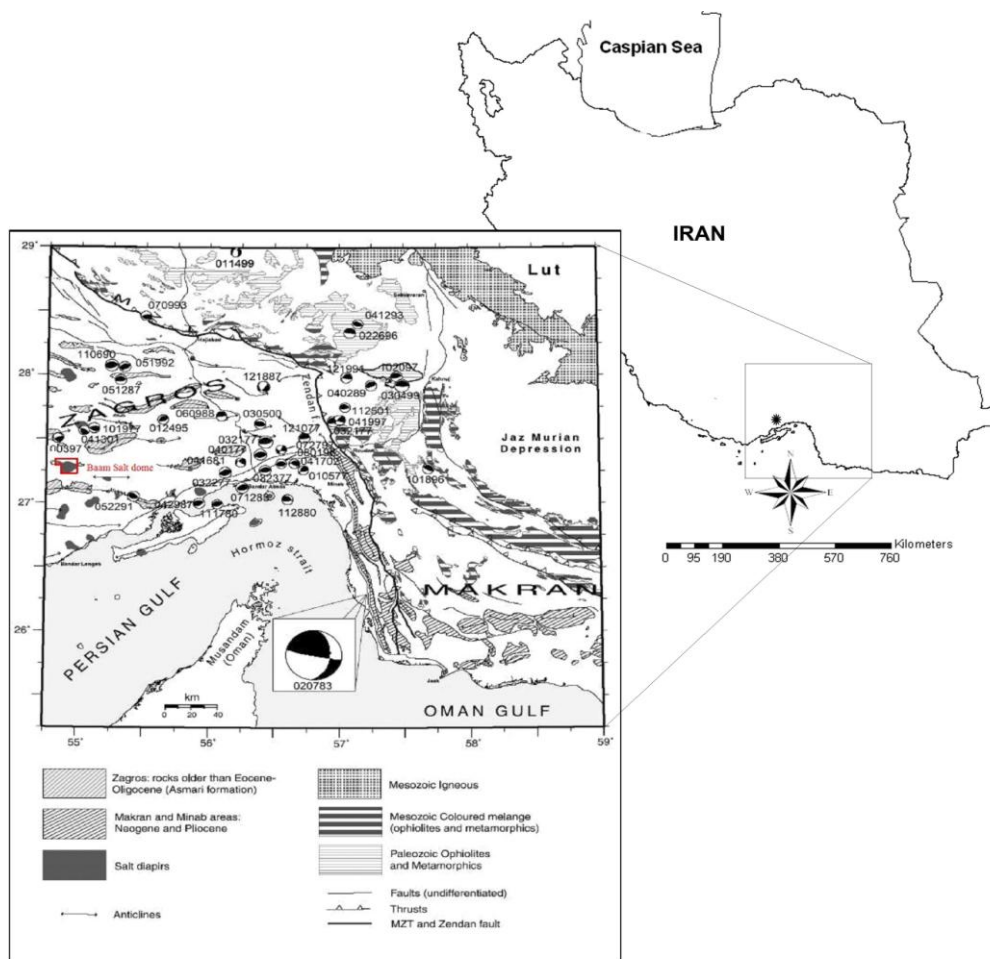
Introduced as the main geomorphologic features, salt domes are scattered particularly in the western parts of the

province. Many salt domes have been detected in the area, among which Siahou, Ahmadi, Larak, Qeshm and Hormoz can be considered as the most remarkable.

The Bam salt dome is located in the western part of Hormozgan Province. The location of regional faults together with their fault plane solutions with respect to major salt domes is presented in Figure 1.

The NE-SW cross section of the Bam salt dome is presented in Figure 2. NW-dipping formations (Ilam, Sarvak, Pabdeh and Gurpi) have fault contacts with SE-dipping (Asmari, Jahrom, Gachsaran and Mishan) formations.

Geological map and cross-section across the dome is also illustrated in Figure 3.



**Fig. 1.** Location and details of the study area

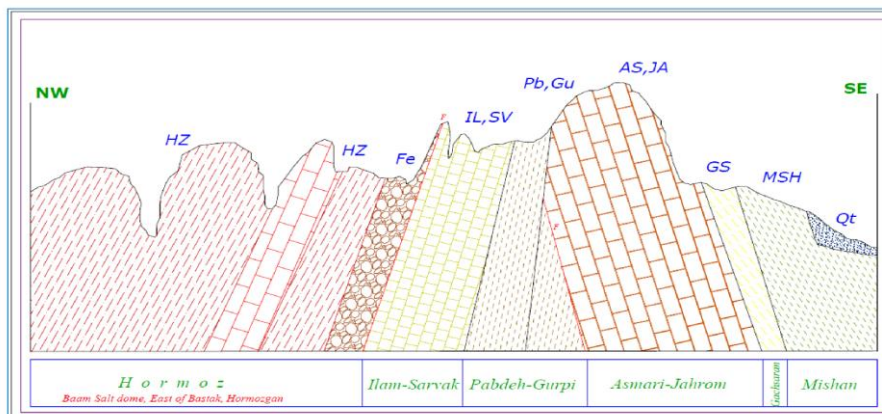


Fig. 2. NE-SW geological cross-section across the Bam salt dome

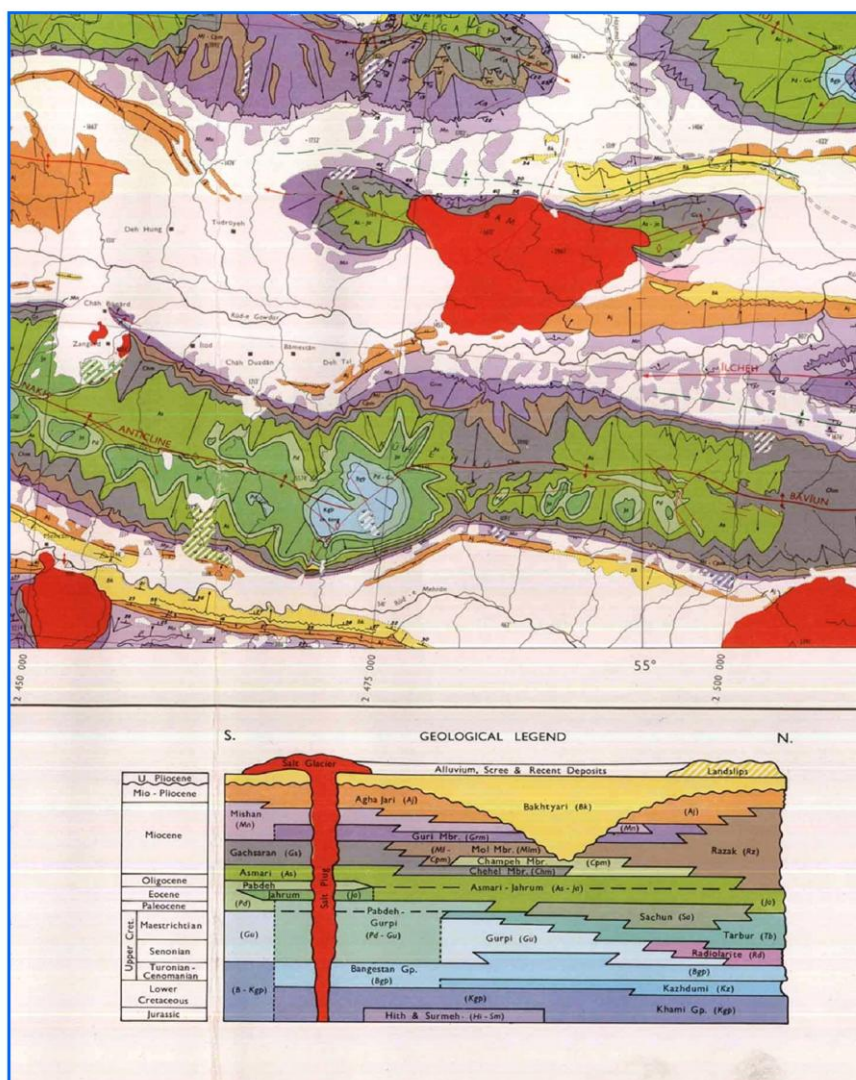
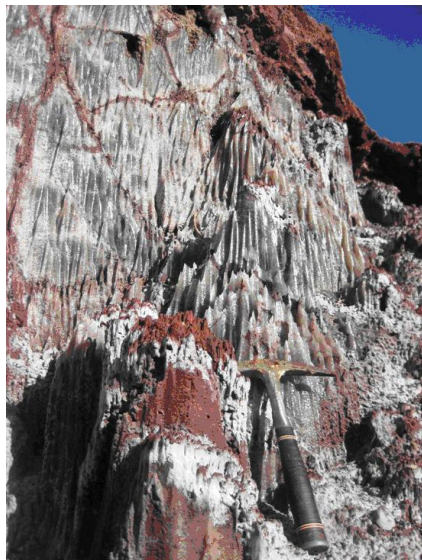


Fig. 3. Geological map and cross section across the Bam salt dome

Dissolution-type weathering in salty and marly units was observed as a dominant issue, particularly in eastern parts of the dome (Fig. 4).



**Fig. 4.** Dissolution-type weathering in salty and marly units in eastern parts of the Bam salt dome

## MATERIALS & METHODS

Two composite samples were collected from salt rocks within the study area and were analysed in a whole-rock quantitative manner using X-ray diffraction instruments for inspecting their mineral compositions (Zhigang et al., 2014). The samples were further analysed by SRXRF. The analyses were carried out using the energy dispersive recording method (Lazareva et al., 2012).

Two composite water samples from the only spring in the area were also collected. Major cations (sodium, potassium, calcium and magnesium), major anions (carbonate, bicarbonate, sulphate and chloride) and some toxic metals/metalloids (Ag, As, Cd, Cu, Co, Hg, Mn, Mo, Ni, Pb, Rb, Sb, Be, Se, Sn, Th,

Ti, V, Zn, U, Al and Fe) were considered for further analysis. In the laboratory, aqueous samples were filtered through polycarbonate filters (0.45 mm pore size) and divided into two parts. One part was used for the analysis of anions, while a second part was treated with 2ml of concentrated HNO<sub>3</sub> for metal analysis. The acid-treated water samples were analysed for the determination of major cations by a further 20-time dilution with ultra-pure water. Ca<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> were measured by flame photometry, while Mg<sup>2+</sup> was determined using a flame atomic absorption spectrometer. In the case of anion concentrations, sulphate, chloride, bicarbonate and carbonate were measured by HACH DR/2000 using method number 8051, an argentometric course using method number 2330, as well as through titration using method number 4500, respectively.

Toxic metals, as well as Al and Fe, were measured using a UNICAM flame atomic absorption spectrometer. Calibration curves were established using known standards. Procedural blanks and duplicates were run alongside the samples as part of the quality assurance programme. The analytical accuracy was approximately  $\pm 5\%$  for all elements.

## RESULTS & DISCUSSION

The results of X-ray diffraction analysis for two samples from salt units are presented in Table 1.

The results indicated that halite was the major mineral, while quartz, anhydrite and dolomite were the minor ones. The presence of anhydrite and dolomite together with quartz has negative effects on edible salt quality.

**Table 1.** The results of XRD analysis for two salt samples (values in percentage)

| Sample | Na    | Cl    | SiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | CaO  | K <sub>2</sub> O | MgO | TiO <sub>2</sub> | MnO  | P <sub>2</sub> O <sub>5</sub> | SO <sub>3</sub> | LOI  |
|--------|-------|-------|------------------|--------------------------------|--------------------------------|------|------------------|-----|------------------|------|-------------------------------|-----------------|------|
| Salt 1 | 37.21 | 57.38 | .43              | .06                            | .29                            | 1.64 | .01              | .13 | .003             | .001 | .002                          | 2.18            | .15  |
| Salt 2 | 34.11 | 52.23 | .10              | .01                            | .13                            | 4.92 | .03              | .93 | .005             | .001 | .012                          | 5.02            | 2.07 |

The results of chemical analyses indicated that Mg, K, Ba and B did not constitute independent salts. High concentrations of sodium and chloride were observed and confirmed salt purity. The content of Fe<sub>2</sub>O<sub>3</sub>, MnO, MgO, Al<sub>2</sub>O<sub>3</sub> and K<sub>2</sub>O were negligible (<0.9 %). CaO content varied between 1.64% and 4.92%.

The concentration of Al and Fe, as well as a variety of toxic metals/metalloids in

the water and salt samples are illustrated in Figure 5. Although some high values were detected in the salt sample, trace elements and heavy metals were mostly negligible in the water samples. Only in sample S2 the metals Cu, Mn, Pb, Rb, Se, V and Zn were detected to be slightly more than ten micrograms per litre.

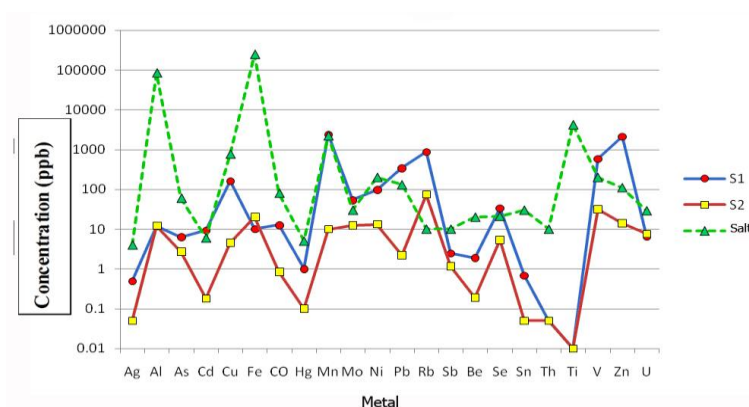


Fig. 5. Metal concentrations in spring water (S1, S2) and salt samples

To establish dominant anions and cations and to introduce the water type, a Piper diagram is presented. As can be seen in Figure 6, the dominant water type was sodium-chloride. However, the S2 sample

indicated a sulphate and calcium content made up of roughly 20 per cent of total anions and cations, respectively. Such a feature may be attributed to anhydrites detected in the geological texture of the study area.

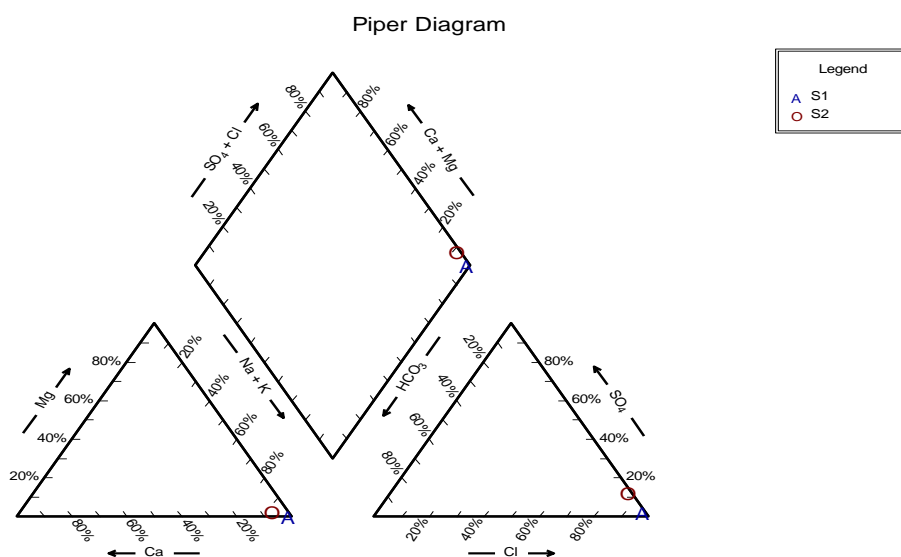


Fig. 6. Dominant anions and cations shown in a Piper diagram

The suitability of water for drinking purposes was evaluated through a Schoeller diagram. The Schoeller diagram

for water samples is shown in Figure 7. As can be seen, the water was not at all suitable for drinking.

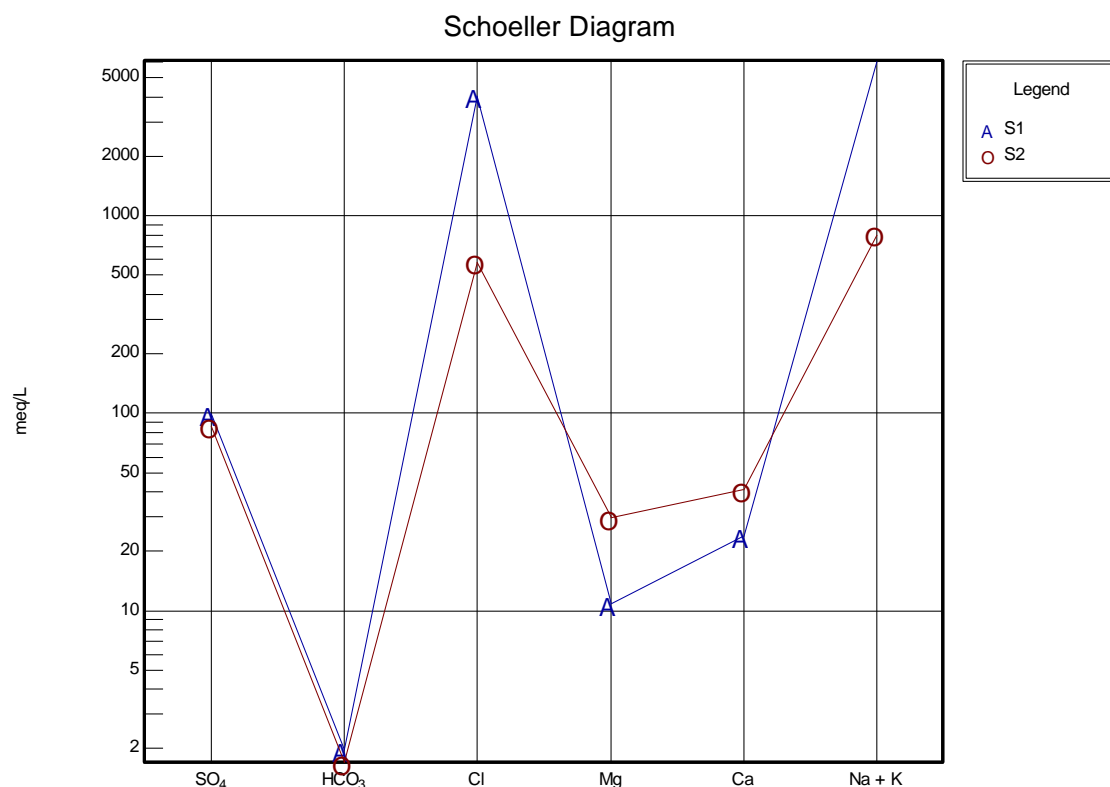


Fig. 7. Schoeller diagram of spring water samples

## CONCLUSION

The evaluation of the geochemistry and hydrochemical quality of the Bam salt dome in Hormozgan Province, located in southern Iran, was conducted in this study. According to the results, the dominant type of regional water was Na+K-Cl, which was different from the common types of fresh water found in Iran (Ca-HCO<sub>3</sub>). The existence of anhydrites justified negligible amounts of calcium and sulphate in water samples. In terms of the Schoeller diagram, the water sample was located within the category not-suitable for drinking. The abundance of salt domes within the area was the main reason for the deterioration of the water quality.

The results of the XRD analysis indicated that halite was the major mineral, while quartz, anhydrite and dolomite were the minor minerals. Remarkably, lower concentrations of toxic metals were observed in water samples compared to the salt sample. This result may be viewed as an opportunity to produce edible salts from the evaporation of spring water. Salts produced through this process would contain significantly less toxic elements compared to existing salt rocks.

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