# Geochemical and Isotopic Evidences of anhydrite-Limestone Asmari Evaporiti caprock, Kupal oil field, Zagros, Iran

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## Abstract:
Cap rock is the main part of petroleum system to preserve hydrocarbons. To evaluate of its characteristics, different methods such as gamma ray and sonic well logs data, petrography and scanning electron microscopic studies, $\delta^{13}C$, $\delta^{18}O$ and $\delta^{34}S$ isotopic analyses were used. The present study is focused on the Asmari cap rock of the Kupal oil field which is located at Dezful embayment, Zagros, Iran. Member one of the Gachsaran evaporitic sediments is commonly considered as the caprock. It consisted of anhydrite, marl, limestone, bituminous shale. It can also be observed halite as a minor part in this lithological variation. The cap rock divided into 6 key beds: A, B, C, D, E, and F. Anhydrite crystals are showing burial textures such as nodular, spherolite, and replacement. SEM observations of halite crystals present hopper and chevron textures. Sulphate sediments in this area are a collection of effects of different diagenetic processes such as anhydritization, cementation, compaction, deformation, recrystalization, replacement and calcitization. Chemical analyses of anhydrite crystals by SEM indicated that replacement process carried out extensively. The process resulted to form dolomite, barite and other chemical changes. Besides of burial textures, the carbon and sulfur isotopes data of anhydrite and limestone samples indicating of sabkha environment, and high burial conditions. Determined $\delta^{13}C$ of limestone varies from -12.1‰, $\delta^{34}S$ of anhydrite samples present a value of 18.3‰ and $\delta^{18}O$ is -0.2 to -0.4‰. These data provided a scenario of brackish fluid which was affected the cap rock sediments.

**Keywords:**
Kupal oil field, Diagenetic processes, Asmari reservoir, SEM

## Introduction:
Cap rock is the main part of petroleum system to preserve hydrocarbons. To study cap rock characteristics, one may be used different methods such as well logs, petrography and isotopic analysis. Well logs are the common graphs to make measurement special parameters and physical properties to depth. In the petroleum view point, to evaluate the cap rock the most important well logs are sonic and gamma ray due to their applications: reduce drilling risk, correlation and facies changes, and lithological zonation. Nevertheless, there are a few publications about cap rock (Alicja, 2003; Rouchy, 2001; Schreiber, and El Tabakh, 2000; El Tabakh et al, 1998; Kasprzyk and Orti, 1998; Pierre, and Rouchy, 1998; Rouchy et al., 1994; Tucker, 1994; Schreiber and Walker, 1992; Hardie, 1990; Spencer, & Lowenstein, 1990; Kendall, & Warren, 1988; Langbein,1987; Shearman, 1978; Gill and Ala, 1972; Kinsman, 1966; Watson, 1960; Slinger, 1948) in comparison to reservoir and source rocks in the world. In Iran, due to giant petroleum fields, there was no interest to evaluate of cap rocks in past. But petroleum geology and oil companies recently changed their views and make attention to cap rock evaluation (Soleimani & Zarvani, 2007). The aim of present study is to investigate lithology and thickness variations, chemical and isotopic analysis of the Kupal oil field cap rock.

## Geological description:
Kupal oil field located at Dezful Embayment, SW of Iran and shows 62 km long and 4 km width. The cap rock consisted of member one of Gachsaran Formation. It is marked lithologically by anhydrite, gypsum, bituminous shale, halite, gray and red marls and

carbonate. It involves of 6 key beds A, B, C, D, E, and F to depth increasing. The cap rock covered Asmari reservoir.

**Methodology:**

Different methods were used to study the Asmari cap rock: a) sonic and gamma ray well logs and correlation charts and cross sections were plotted using log plot 2003 software, b) Petrography analysis of 400 thin sections, and also scanning electron microscope (Leo 1455 vp model) with EDS analyzer, c) isotopic measurement were made on selected samples of anhydrite, carbonate and bituminous shale which were sent to Humble geochemical laboratory to analyse $\delta^{13}C$ and $\delta^{34}S$ and $\delta^{18}O$.

**Discussion:**

The cap rock of Kupal oil field consisted lithologicaly of anhydrite, halite and limestone. The cap rock thickness using gamma ray and sonic well logs data revealed that is varied through the field and increased from SE to NW (Fig. 1). These changes related to plastic property of the cap rock. The assessments of thin sections petrography with well logs data resulted to divide the cap rock into 6 key beds as follow:

Key bed A- It consists of gray to white anhydrite which they are partially crystalline and transparent represent nodular texture (Fig. 2B), spherolithic(Figs. 2C and 2G), porphyroblast (Fig. 2E), replacement (Fig. 2J), fluvial (Fig. 2L), microgranular (Fig. 3G) and star shape (Fig. 3K). Anhydrite and halite forms net texture (Fig 3A). Microscopically anhydrite crystals are lath (Fig. 2K) or fibers. D, D2, E dolomite (Fig. 2A) and matchstick dolomite crystals were observed. Sometimes, it has filled the pores (Fig. 2I) Accessory observable minerals include pyrite and chalcedony. Bed thickness is 10–20 ft and sometimes reaches to 3.5m. Key bed A terminates to salt member as the top (member two of Gachsaran Formation) and to bituminous shale (Fig. 2F) of key bed B at the bottom. It may be showing intervals of halite which presents individual textures such as Hupper and chevron (Figs. 3E and 3F). Sparse automorphous crystals of calcite were also identified in anhydrite matrix (Fig. 3H).

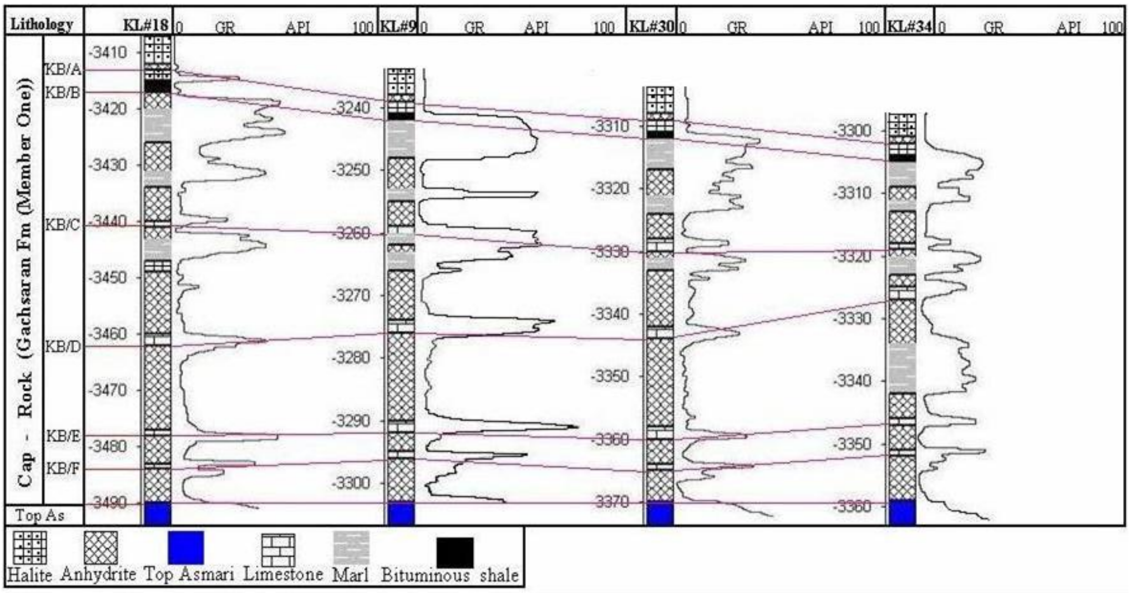


Fig.1- General stratigraphic column correlation and Gamma Ray Log. Depth is in per meter.

Key bed B - It is deep brown to black bituminous shale (Fig. 2F, 3C) with sparse particles of silt, sands, pyrite and often anhydrite. It burns easily at match flame and produces rubber firing smile. These bituminous matters solve in chloroform and form a brown–yellow solution. This guide horizon observes as lamina with 15 – 75cm. The thickness variation is not important. Key bed B is considered as an important key bed in Zagros oil field, NW– SW of Iran.

Key bed C- Consisted of cream-gray limestone. It is also called upper limestone or upper chilostomellide limestone. It changes laterally to organic bearing mudstone and anhydrite. It classify as mudstone– wackstone. In some cases, it changes into silty, sandy and pseudo oolithic limestone.

Key bed D- It defines as gray to light fine–medium crystals of limestone, called also lower chilostomellide limestone. Wackstone–mudstone and pseudo oolithic limestone (Fig. 2D) are observed which can make a quiet lagoonal environment.

Key bed E- It is light gray to brown mudstone with partially recrystalization and no fossils. In this internal needle like crystals of anhydrite, quartz and calcite are also formed minor phases.

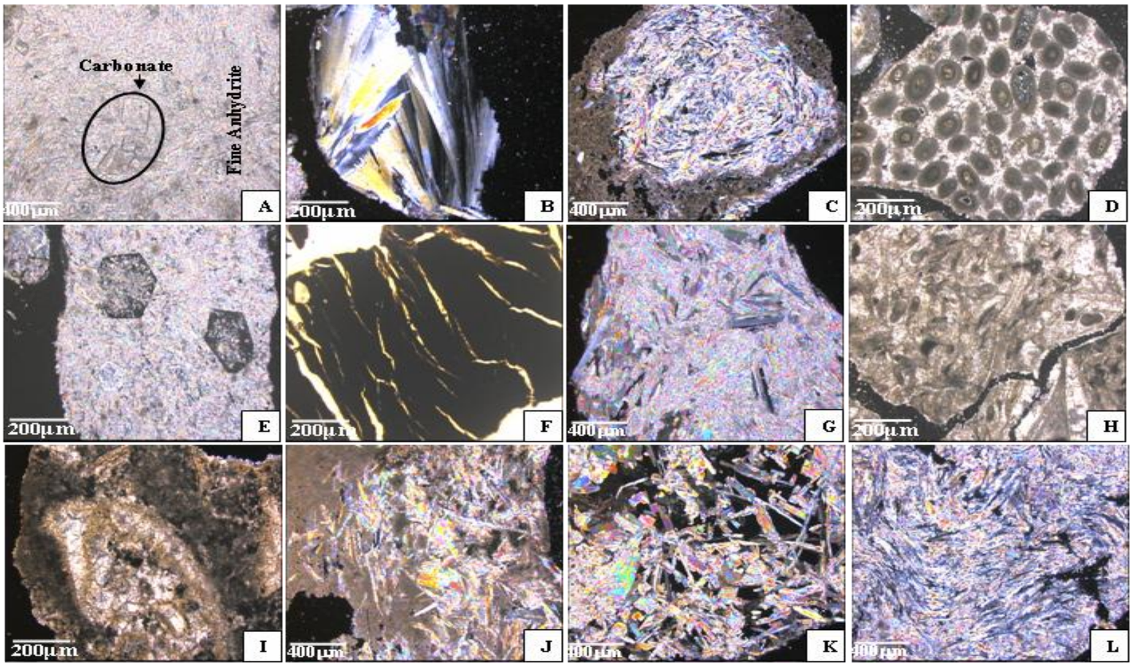


Fig.2- Evaporitic textures observed in the cap rock of Kupal oil field:
A)-Dolomite D2 in matrix (well 3, 3269m); B)-Spherolitic (well 3, 3280m); C)-Nodular (well 34, 3268m); D)- Calcareous pseudo oolite in anhydrite matrix, (well 1, 3307m); E)-Porphyroblast gypsum (well 38, 3313m); F)-Bituminous shale (well12, 3292m); G)- Porphyroblast anhydrite (well 32, 3274m); H)-Gray algal limestone with pore filling anhydrite (well 3, 3371m); I)- Pore filling dolomite (well 1, 3308m); J)- Anhydrite replaced in mudstone (well 22, 3288m); K)- Lath anhydrite (well 1, 3226m) and L)- Fluvial anhydrite (well 18, 3334m).

Key bed F- Light gray to pale brown limestone with recrystalization is the main components. Clay minerals, sand grains and celestin are minor contents. Key bed F often contains algal limestone (Fig. 2H). This key bed divided into two parts, F2 (upper part) and F1 (lower part). There is possible that the key bed contaminated with hydrocarbon particles due to adjacent of Asmari reservoir.

Petrographic studies indicated that the following diagenetic processes are dominant: anhydritization, cementation, compaction, replacement and recrystalization.

1) Anhydritization- One of the syndepositional evidence of anhydritization is the nodular and mosaic–nodular anhydrite in the caprock, presents a platform edge or sabkha environment (Shearman, 1985; Rouchy et al, 1994). These types of anhydrite as well as large pseudomorph of anhydrite and lath crystals are considered to be common forms of primary anhydritization.

2) Cementation- This process is the main factor to preserve anhydrite pseudomorphs against load and pore–water pressure. These pseudomorphs resulted from primary gypsum replacement. Its inherited morphology retained by cementation process (Kasprzyk, 1995). Anhydrite appears to have such forms as nodular, cements and laminar. Their crystals size varies up to 50mμ. Spary anhydrite observed where some parts removed by solution and thus porosity produced well. spary anhydrite crystals size is up to 2 mμ. Anhydrite cement appears to form several fabrics such random and decussate, occupied intra crystal, inter granular and pores. In some cases, spary anhydrite crystals are formed in the clastic quartz zones.

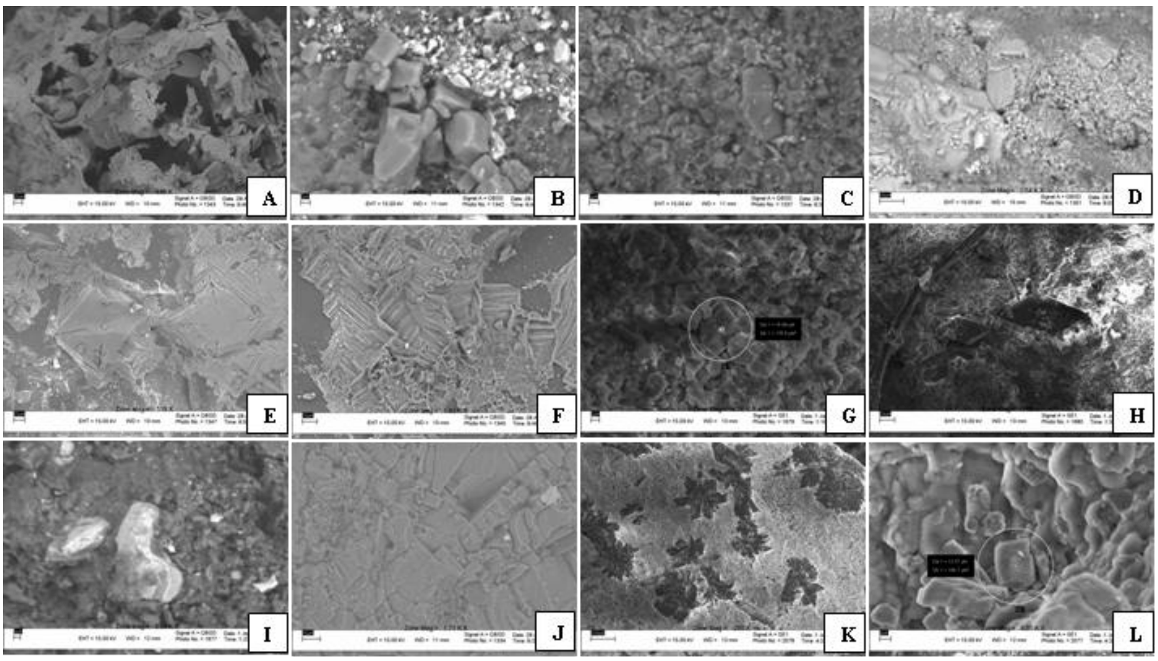

Fig.3- SEM photographs of some caprock samples: A)-Network anhydrite with dissolved halite pores (well 25, 3288m); B)-Euhedral anhydrite crystals (well19, 3389m); C)- Shale (well 4, 3366m); D)-Deformed anhydrite (well 40, 3395m); E & F)- Hupper and chevron textures in halite (well 4, 3449m); G)- Euhedral anhydrite (well 30, 3306); H)-Automorph calcite in anhydrite matrix (well 22, 3355m); I)- Barite crystals (well 30, 3314m); J)- Compact anhydrite (well 30, 3366m); K)Star shaped anhydrite (well40, 3376m); and L)- Rhombohedron anhydrite (well 25, 3289m).

3) Recrystalization- Anhydrite crystals are undergone sever deformation which is related to large and blocky crystals. It seems spary and large grains of anhydrite formed by deep burial or recrystalization of fine anhydrite crystals (El Tabakh et al, 2004).

4) Compaction- Different physical composition of primary gypsum sediments is the main factor to control anhydrite fabrics and anhydritization. During burial, anhydrite crystals deformed (Fig. 3D), and recrystalised. After passing elastic critical threshold, crystals were broken and forms rearrangement (Fig. 3B). It seems compaction process (Fig. 3J) occurred pre-anhydritization. Compaction results to gypsum dehydration, reduces column thicknesses and introduces dissolution pores.

5) Replacement and calcitization: Diagenetic fluids cause unstable minerals to dissolve and replace by new stable mineral phase such as barite (Fig. 3I), anhydrite as pseudo calcite (Fig. 3L). These diagenetic changes could be occurred as replacement of primary gypsum and carbonate by diagenetic anhydrite or carbonate.

Isotopic carbon, oxygen and sulfur isotopes data of anhydrite and limestone samples are indicate that $\delta^{13}C$ of limestone varies from -12.1 to 12.4‰, $\delta^{34}S$ of anhydrite 18.3‰ and $\delta^{18}O$ is -0.2 to -0.4‰. These values as well as burial textures are indicating sabkha environment, and high burial conditions.

**Concluding remarks:**

1-The main component of cap rock is anhydrite, but it decreases to depth.

2- Interbeded halite solely observed in the SW part of the oil field.

3- Calcitization, replacement, anhydritization, compaction and recrystalization are dominant diagenetic processes.

4- Lath, replacement, spherolitic, nodular textures in anhydrite intervals and chevron and hopper textures in halite samples are observable.

5- Anhydrite crystals changed chemically and replaced by Ba sulfate.

6- Cap rock thickness indicating variation from SE to NW.

7-Petrographicaly, chemical, isotopic analyses demonstrated sabkha/ lagoonal environment.

**Acknowledgments**

We should express our thanks to Shahid Chamran University authorities. Special thank to Dr. Amiri Bakhtiar, the Head of Geology Department of NISOC, for their supporting.

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