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Geochemical Characteristics of Late Cretaceous Limestone of Bangestan Group in Izeh Zone, Zagros Basin, Iran

E. Asadi Mehmandosti[a], and M. H. Adabi[b]

[a.] Department of Geology, Faculty of Earth Sciences, Kharazmi University, Mofatteh Av., Tehran, Iran; [b.] School of Earth Sciences, Shahid Beheshti University, Evin, Tehran, Iran

Presenting author, E-mail: e.asadi@khu.ac.ir

Abstract

The Bangestan group forming the second most important reservoir rocks in Iran, so the late Cretaceous carbonates of this group with Santonian to Campanion in ages were studied geochemically in 3 outcrop sections in Izeh Zone. For better understanding of sedimentary characteristics in the Zagros area of Iran as main targets for hydrocarbon exploration, 102 and 60 samples respectively were analyzed for elemental (Ca, Mg, Sr, Na, Fe, Mn) and isotopic (oxygen and carbon) studies in Payun, Kuh-e Gurpi and Kuh-e Mangasht outcrops in the Izeh zone. High Sr/Mn ratios and Sr content with heaviest oxygen isotopes of the studied carbonates indicate lower dissolution processes, extensive rock-water interaction (WRI), and a closed diagenetic system. Carbon and oxygen isotope variations suggest marine phreatic diagenesis for more studied samples. The least-altered carbonate sample, with an oxygen isotope value of -3.21‰ PDB, was used to calculate a temperature during the relatively shallow burial, using the equation of Anderson and Arthur, 1983. This calculation gives an early shallow burial fluid temperature of about 26 C. Furthermore, the average of Sr/Na concentration is around 5 which are similar to recent warm-water aragonite and might indicate the original aragonite mineralogy for studied carbonates. Geochemical difference which observed in studied sections at Izeh zone could be related to the reactivation of deep seated structures such as Hendijan and Bahregansar (Izeh) faults which caused thickness, facies and diagenetic variations in these areas.

Introduction

The Zagros fold-and-thrust belt extends for about 1800 km through Iraq and southern Iran, and with the associated foreland basin, represents one of the oldest and richest hydrocarbon provinces known (1). In addition, the Bangestan Group (Albian-Campanian in age) hosts some of the most prolific reservoirs of the Arabian Platform and Zagros fold-thrust belt hydrocarbon provinces. The most important interval of this group includes neritic carbonates of the Sarvak (Albian to Cenomanian) and Ilam (Santonian to Campanian) formations (2, 3). Accordingly, the Ilam Formation and its equivalents contain important reservoir intervals in south and southwest Iran (including Dezful Embayment) and throughout the Middle East (3, 4, 5, 6, 7, 8). The aim of this research is to examine geochemical characteristics of late Cretaceous carbonates of the Ilam Formation in 3 outcrops in the Izeh zone, for better understanding of sedimentary characteristics in Zagros area, Iran.

Geological Setting

Three outcrop sections with a total thickness of 380 m, including: Payun (thickness of 95 m), Kuh-e Mangasht (thickness of 228 m), Kuh-e Gurpi (thickness of 57 m) which situated in the Izeh zone (Fig. 1), Zagros fold-thrust belt was selected to study (data from 4, 9, 10). The Zagros fold-and-thrust belt can be divided into a number of zones (Lurestan, Izeh, Dezful Embayment, Fars, High Zagros), which differ according to their structural style and sedimentary history. The Izeh zone lies across a sharp topographical break to the southwest of the High Zagros fault. This zone consists of a variety of structures of variable sizes and geometric characteristics. The boundary of the Izeh zone coincides with the Balarud, Kazerun, Mountain Front and High Zagros Faults. Hendijan-Izeh fault is one of the important lineaments that have Arabian tectonic trend and refer of a syncline structure in Arabian plate.

Results and Discussion

Study of the major elements (Ca, Mg), trace elements (Sr, Na, Fe, Mn) and stable carbon and oxygen isotopes of Ilam limestone can lead to understand geochemical and diagenetic characteristics of carbonate rocks in the Izeh zone (4, 9, 10). So, 102 powdered micritic samples from the selected outcrops were analyzed by atomic absorption spectrometry at the Geology Department of Shahid Beheshti University, Tehran, Iran. Sixty powdered samples, which had previously been analyzed for major and minor elements, were analyzed with a Micromass, for oxygen and carbon isotopes at the Central Science Laboratory, University of Tasmania, Australia.

Geochemical analysis shows that the averages amount of Sr, Na and Fe in the Ilam limestones from kuh-e Gurpi are higher than Kuh-e Mangasht and Payun carbonates. However, the average amount of Mn in Kuh-e Mangasht and Payun are higher than this section (Table 1). The mean of oxygen isotopes of kuh-e Gurpi are more than other sections while, the Payun carbonates have the higher average of carbon isotopes in compare to kuh-e Gurpi and Kuh-e Mangasht samples (Table 1).

In figure 2 variation of Sr plotted versus Na. As it can be seen Kuh-e Gurpi samples separated from Kuh-e Mangasht and Payun carbonates due to higher amount of Sr and Na concentrations. Sr values decrease from modern to ancient limestones and dolomites (11). Modern shallow marine abiotic aragonite is characterized by high Sr values (up to 10000 ppm), while abiotic calcite has lower amounts of strontium (12). The incorporation of Sr in carbonates depends on the primary mineralogy, water temperature, salinity, vital effects, and average Ca/Sr content of seawater (11). Most ancient limestones lose Sr during neomorphic processes, such as the transformation of aragonite to calcite, dissolution, and under open diagenetic systems (4, 11, 12). The higher Sr concentrations of samples from the Kuh-Gurpi may indicate either (a) greater amounts of primary aragonite at that locale, or (b) a more closed diagenetic system, resulting in retention of more Sr in secondary carbonate phases. The low Na concentrations of Payun and Kuh-e Mangasht samples indicate that the Ilam Formation carbonates of these sections might have recrystallized during burial marine settings which will result in the loss of Na from the carbonates in compare to Kuh-e Gurpi carbonates.

Bathurst (13) suggested that limestone diagenesis is mainly a wet dissolution and precipitation process. During dissolution and conversion of metastable aragonite and hig-Mg calcite to stable low-Mg calcite, Sr concentrations decrease and Mn concentrations increase. This process is greatly facilitated by subaerial exposure and fresh water influx (14), resulting in low Sr/Mn ratios. Therefore, covariance of Sr/Mn with Mn provides a useful measure of the degree of dissolution in limestone (15). The Plot of Sr/Mn-Mn variation (Fig 3) shows that Kuh-e Gurpi carbonates have lower amount of dissolution or alteration in compare to Payun and Kuh-e Mangasht.

Researchers believe that Modern and ancient tropical carbonates differ from their non-tropical counterparts by their Sr/Na ratio and Mn contents (15, 16). Modern tropical aragonitic sediments have low Mn, and high Sr/Na ratio from (3 to ~5); in contrast, modern temperate bulk carbonates have high Mn, and low Sr/Na ratios (~1). Subpolar Permian cold-water fossils and the Permian subpolar bulk cold-water limestones also have a Sr/Na ratio of ~1 (15). In the Ilam limestone (Fig. 4), Sr/Na concentrations range from 3 to 9 (mean 5); this is similar to recent warm-water aragonite mineralogy (17, 18).

Variation of oxygen isotopes versus Mn in figure 5 and comparing the data with Burlington limestone of Mississippi of USA (CM), Silurian Readbay carbonates of Canada (Cs) and recent carbonates (R) show the closed to semi closed diagenetic system during deposition of Ilam carbonates(19).

Cross plot of $\delta18O$-$\delta13C$ values from Ilam limestone in studied sections (Fig. 6) suggest diagenetic alteration occurred in marine phreatic setting for kuh-e Gurpi and Payun carbonates. Isotopic values also illustrate that in Kuh-e Mangasht carbonate samples altered by meteoric diagenesis. The variation of carbon isotope in meteoric diagenetic processes is more than oxygen isotope due to oxidation of organic matter in soil, thus, it shows typical of inverted J trend.

The least-altered carbonate sample, with a d18O value of - 3.21‰ PDB, was used to calculate a temperature during the relatively shallow burial, using the equation of Anderson and Arthur, (20):

$$T\ (°C) = 16.9 – 4.38\ (δC – δW) + 0.10\ (δC – δW)^2$$

Where T is temperature (in °C), δC is the heaviest measured oxygen isotope value and δW is the oxygen isotope values of marine water in the Cretaceous (in SMOW), which is equal to -1 ‰ SMOW (21, 22). This calculation gives an early shallow burial fluid temperature of about 26 °C.

Geochemical difference which observed in studied sections at the Izeh zone, can be related to different in original carbonate mineralogy, facies distribution, salinity, biological fractionation and depth of basin during deposition of Ilam carbonates. Moreover, tectonic conditions in the Izeh zone might affect on this variations. Study of Kazerun, Izeh and Balarud faults as bounding fault of the Izeh zone show that these faults affected the sedimentary conditions of basin, thickness and facies of different formations (23). Investigation of isopach maps in the Izeh zone and the Dezful Embayment show the existence of several local decollement levels in the Zagros sedimentary cover (24). Furthermore, researchers believe that reactivation of deep seated structures such as Hendijan and Bahregansar (Izeh) faults which cause thickness, facies and diagenetic variations in these areas (24).

Conclusions

Based upon the present studies, the geochemical characteristics of the Ilam Formation changes in the Izeh zone, Zagros, Iran in 3 studied outcrops. It has been found that the carbonate of the Kuh-e Gurpi has lower amount of dissolution or alteration and might be precipitate in more closed diagenetic system in compare to Payun and Kuh-e Mangasht sections. Based upon the isotopic data, Kuh-e Mangasht limestones show meteoric diagenesis while two other sections indicate marine phreatic diagenesis. Geochemical difference which observed in studied sections at the Izeh zone, can related to differential in original carbonate mineralogy, facies distribution, salinity, biological fractionation and depth of basin during deposition of Ilam carbonates. Moreover the reactivation of deep seated structures such as Hendijan and Bahregansar (Izeh) faults which caused thickness, facies and diagenetic variations in these areas.

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Table 1: Average amount of geochemical data in studied sections.

outcrops	Ca %	Mg %	Sr ppm	Na ppm	Mn ppm	Fe ppm	Oxygen ‰PDB	Carbon ‰PDB
Payun	37.8	0.3	508.6	160.1	24.4	65.1	-4.22	2.32
Kuh-e Mangasht	39.2	0.2	680.2	274.4	48.5	112.8	-4.13	1.21
Kuhe-e Gurpi	38.5	0.5	3130.3	338.8	18.5	309.9	-3.81	2.14

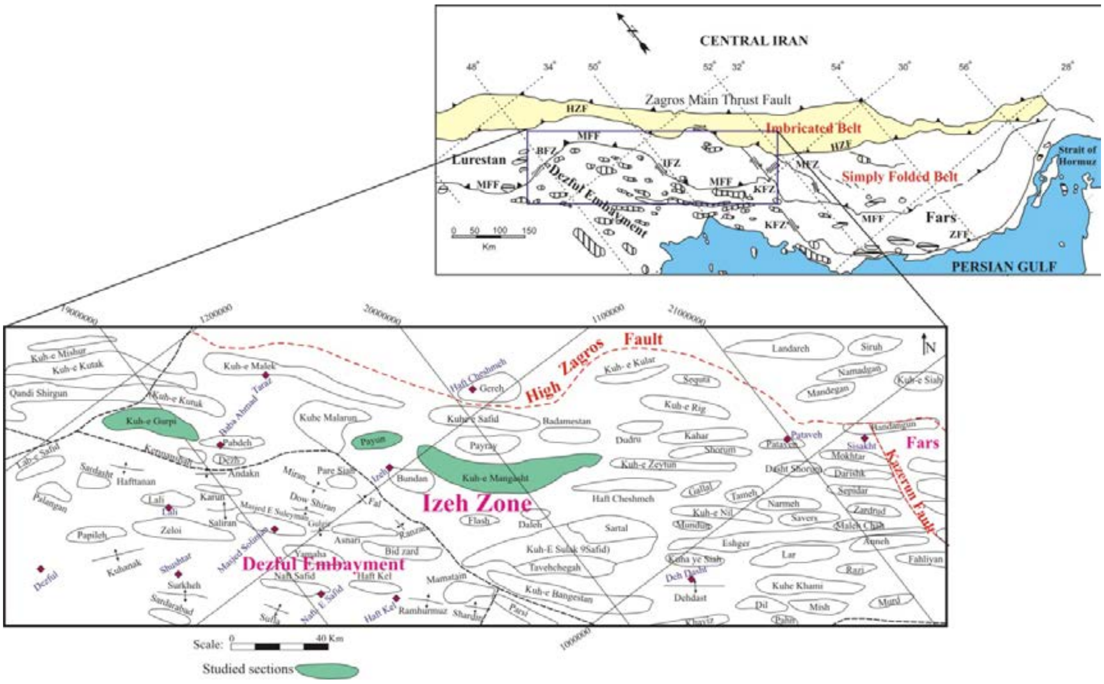

Figure 1. Subdivisions of the Zagros orogenic belt (modified from 23) and locality map of the studied sections.

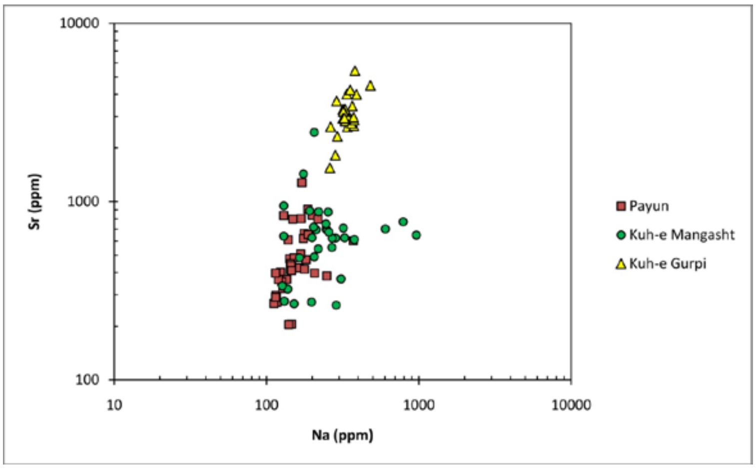

Figure 2. Variation of Sr versus Na.

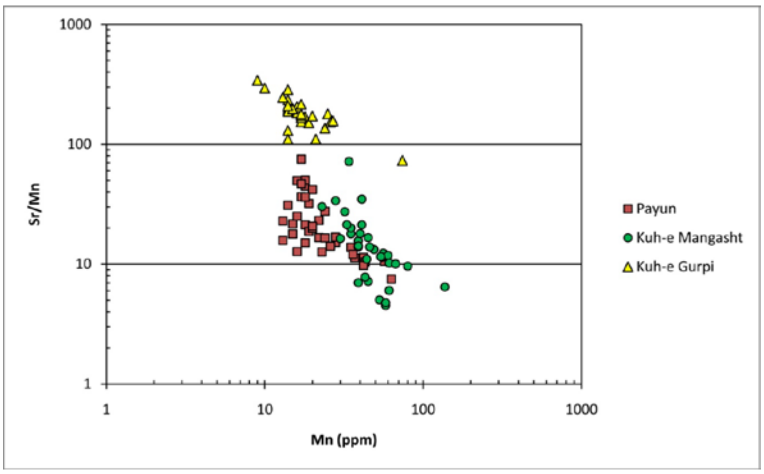

Figure 3. Variation of Sr/Mn versus Mn.

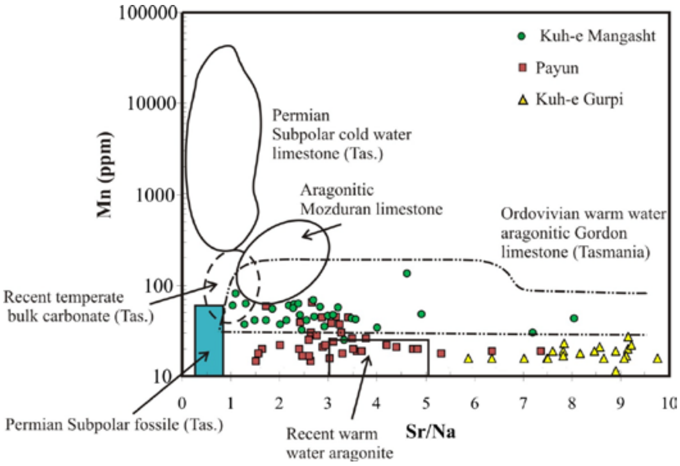

Figure 4. Plot of Mn content versus Sr/Na.

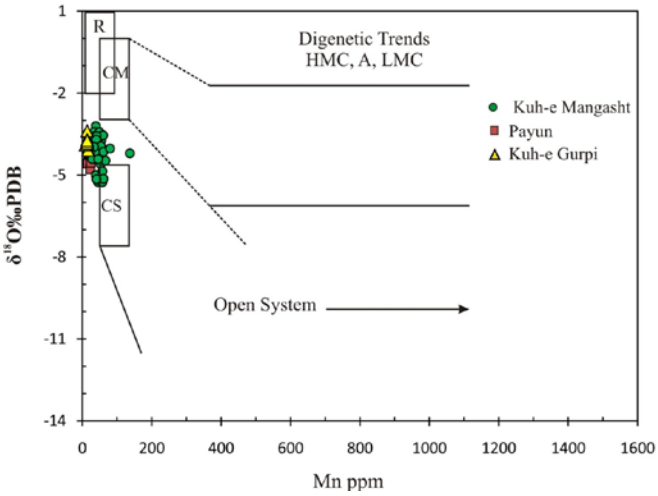

Figure 5. Variation of Oxygen isotopes versus Mn.

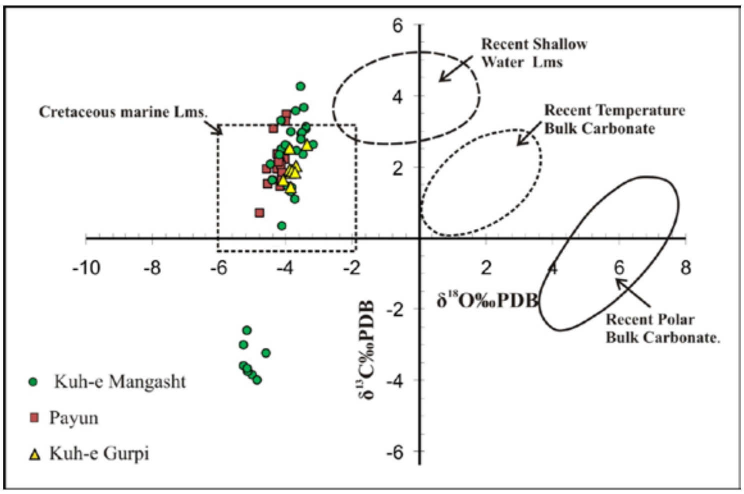

Figure 6. Cross-plot of carbon and oxygen isotopes data from the Ilam Formation in studied sections.