Fluid inclusion analysis and geochemical characteristics of Jurassic carbonates: Case study from High Zagros zone, Kohrang area, SW Iran

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Abstract

The Surmeh Formation with the age of Jurassic composed of shallow-water limestones and dolomites. The study area is located in the southwest of Iran in the Kohkiluyeh Province. Fluid inclusion analysis can be a good approach for studying trend diagenesis of cements in carbonate rocks. Petrographic observation of the Surmeh Formation reveals the presence of 10 different cements related to various diagenetic environments. This study attempts to determine the temperature of cement precipitation, the salinity of the fluid from which the cement precipitated and the diagenetic environments. Frequency histograms of Th (temperature of homogenization) and bivariate plot of Th and Tm_{ice} *(temperature of final ice melting) show distinct areas for each cement. Also, the petrographic observation and fluid inclusion data (Th and* Tm_{ice} *) reveal that timing of precipitation of 5 types of coarse-crystalline cements in this successtion , began from meteoric diagenesis and continue to deep burial diagenesis. All of fluid inclusions exhibit two-phases (liquid-vapour phase), which the liquid ratios is more than vapour ratios. In addition, trace element and isotopic geochemistry of carbonates from different environments can be used as a powerful tool for determination of paleoenvironmental and original mineralogy of carbonates rocks. Major and minor elements and carbon and oxygen isotopes values were used to determine the original carbonate mineralogy of Surmeh Formation. In this research, petrographic evidence, elemental, oxygen and carbon isotopes values indicate that aragonite was the original carbonate mineralogy in this formation. Bivariate plot of Sr/Ca values versus Mn, also illustrate that Surmeh carbonates were affected by non-marine diagenesis in a closed to semi-closed* system.

Keywords: *Fluid Inclusion, Surmeh Formation, Kohrang area, Kohkiluyeh Province.*

Introduction

Fluid inclusions have been extensively applied in igneous, metamorphic and economic geology studies where the temperature and salinity of precipitating fluids need to be determined. More recently, they have also been used to study the diagenetic history of carbonate sequences (Goldstein and Reynolds 1994; Qing and Mountjoy 1994; Qing et al., 2006). Most diagenetic systems are closely linked to temperature and salinity of the fluid, thus fluid inclusions are sensitive indicators of paleotemperature of diagenetic environments. This study attempts to determine the temperature of cement precipitation, the salinity of the fluid from which the cement precipitated and the diagenetic environments.

In addition, isotope and trace element geochemistry of carbonates from basinal environments can be used as a powerful tool for recognition of original mineralogy (Vincent et al. 2006). Some workers have argued that the mineralogy of ancient carbonates may have been different from that of modern sediments, with calcite being considered the dominant mineral during the Ordovician, Devonian-mid Carboniferous and Jurassic-Cretaceous to Early/Middle Cenozoic. Variation in carbonate mineralogy has been related to the position of global sea level (Wilkinson et al., 1985), changes in rates of seafloor spreading (e.g. Hardie, 1996), P_{CO2} level (e.g. Sandberg, 1985) and Mg/Ca ratio related to spreading rate (e.g. Stanly and Hardie, 1998).

Geological setting

The section is situated in the northwest of Kohrang city, and 3 km west of Ghaletak village in Kohliluyeh Province in SW of Iran (Fig.1). The Surmeh formation, which is part of the Khami Group consists of 405 m of shallow-water limestones and dolomites.

Methods of study

Approximately 200 uncovered thin sections were prepared for petrographic and diagenetic study. eight samples were selected for fluid inclusion studies and double polished-thick sections were obtained using the "cold preparation techniques" (Goldstein and Reynolds, 1994) to avoid re-equilibration of fluid inclusions. The microthermometric measurements were performed using a Linkam THMS600 heating - freezing stage. In addition, Powders of 33 samples of limestones were analysed by atomic absorption spectrometer for Ca, Mg, Sr, Na, Mn, Fe at the Geology Department of the Shahid Beheshti University, Tehran. Precision was ±0.5% for Ca and Mg and ±5 ppm for Sr, Na, Mn and Fe. For oxygen and carbon isotopic analysis, 19 powdered of limestone samples were analysed with a Micromass, 602D, at the Central Science Laboratory, University of Tasmania, Australia. Precision of data is ±0.1‰ for both δ18O and δ13C.

Fluid inclusion and interpretation of diagenesis

There are some diagenetic processes in Surmeh Formation such as mechanical and chemical compaction, cementation, silicification, micritization, dolomitization, bioturbation, dissolution and neomorphism. Calcite and dolomite cementation is an important aspect of the diagenetic history of Surmeh Formation. Petrographic observation of these carbonates reveals the presence of 10 different cements related to various diagenetic environments. Microthermometric measurements of fluid inclusions for some of these cements were impossible, because the size of crystalls of these cements were very small and fluid inclusion within these cements were very small too. The following conclusions are based on detailed fluid inclusion study which performed on 5 types of coarse-crystalline cements: All of fluid inclusions exhibit two-phases (liquid-vapour phase) which the liquid ratios is more than vapour ratios in all of them.

1- fluid inclusion analysis of equant calcite cement resulted in Th values (temperature of homogenization) range from 64.3 to 78.2 ° C and salinity values range from 23.3 to 24.3° C weight % NaCl equivalent, that indicate precipitation saline fluids at moderate temperatures. The composition of this fluid are similar to composition of meteoric fluids. 2- blocky calcite cement with fluid inclusion evidence (Th values range from 84.2 to 98.4°C and salinity values range from 19.6 to 22.3°C weight % NaCl equivalent) imply precipitation from saline brine at elevated temperatures. Blocky cement is interpreted as having formed in meteoric to shallow burial diagenesis. 3- fracture-filling calcite cement with fluid inclusion evidence (Th values range from 116 to 131.2° C and salinity values range from 7.73 to 9.73° C weight % NaCl equivalent) imply precipitation from a low saline fluids at elevated temperatures. This cement is therefore a shallow to intermediate burial diagenetic phase. 4- pore-filling dolomite cement with Th values (90-116° C) and salinity values (17.9-18.7°C weight % NaCl equivalent) is probably formed in intermediate to deep burial diagenesis. 5- fracture-filling dolomite cement has a highest Th values (142-188.5° C) and the lowest salinities (6.52-7.70°C weight % NaCl equivalent) that is recognized as a product of late diagenetic deep burial (Qing etal., 2006).

Geochemistry of limestones

Trace elements

Sr: The concentration of Sr in recent tropical carbonate sediments ranges from 8000 to 10,000 ppm, whereas in recent temperate carbonates it ranges from 1642 to 5007 ppm (Adabi and Rao, 1991). Sr increases with increasing aragonite content (Adabi and Rao, 1991) and decreases with increasing calcite content. Concentrations of Sr have also been directly related to increasing water temperature (Morse and Mackenzie, 1990). The concentration of Sr in the Surmeh limestone samples ranges from 552 to 1420 ppm (Fig 2.A). Sr values of these samples indicate moderate diagenesis. This is due to the replacement of aragonite by calcite, probably during two stages of diagenetic stabilization.

Mn: The concentration of Mn in the Surmeh limestone samples ranges from 24 to 732 ppm. In modern warm-water aragonite, Mn and Fe concentrations are less than 20 ppm (Milliman, 1974). The low Mn concentration may indicate an original aragonite mineralogy. The bivariate plot of Sr/Ca versus Mn shows that the limestones have been stabilized by fluids in a closed to semi-closed diagenetic system (Fig 2.A).

Oxygen and carbon isotopes

The stable isotopes of carbon and oxygen are the most commonly used isotopes in diagenetic studies of carbonates. The fluids that precipitate calcite and dolomite can be characterized by their isotopic compositions. The δ 18O values in the Surmeh limestone range from -3.49 ‰ to -10.53 ‰ PDB, whereas δ 13C values range from 2.97 ‰ to -4.61 ‰ PDB (Fig 2.B). In Surmeh Formation, Depleted in δ18O values is due to effect of burial diagenesis, while depleted in δ13C values was related to effect of meteoric diagenesis. Bivariate plots of trace elements versus carbon and oxygen isotope values were used to determine original carbonate mineralogy.

Conclusion

The Surmeh Formation, in high Zagros zone, is a 405 m sequence of shallow-water limestones and dolomites rocks. The present study indicates that there are some diagenetic processes in this formation such as mechanical and chemical compaction, cementation, silicification, micritization, dolomitization, bioturbation, dissolution and neomorphism. Calcite and dolomite cementation is an important aspect of the diagenetic history of Surmeh Fromation. Petrographic observation of these carbonates reveals the presence of 10 different cements related to various diagenetic environments. Based on petrographic observation and fluid inclusion data reveals that timing of precipitation of cements in this sequence, began from marine diagenesis and continue to meteoric and deep burial diagenesis. Bivariate plots of minor and major elements, oxygen and carbon isotope values, along with petrographic studies indicate that the original carbonate mineralogy was dominantly aragonite in the Surmeh Formation. Geochemical studies also showed that limestone rocks were mostly affected by meteoric diagenesis in closed to semi-closed system.

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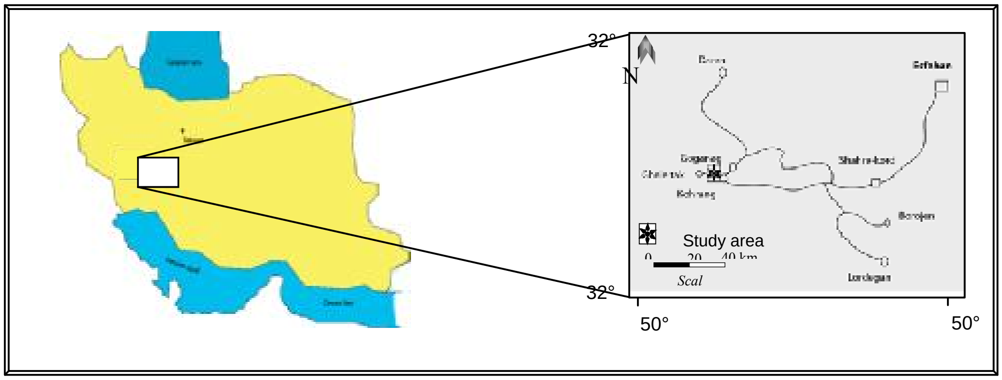

Fig. 1. Location map of the study area in Kohkiluyeh Province, Iran.

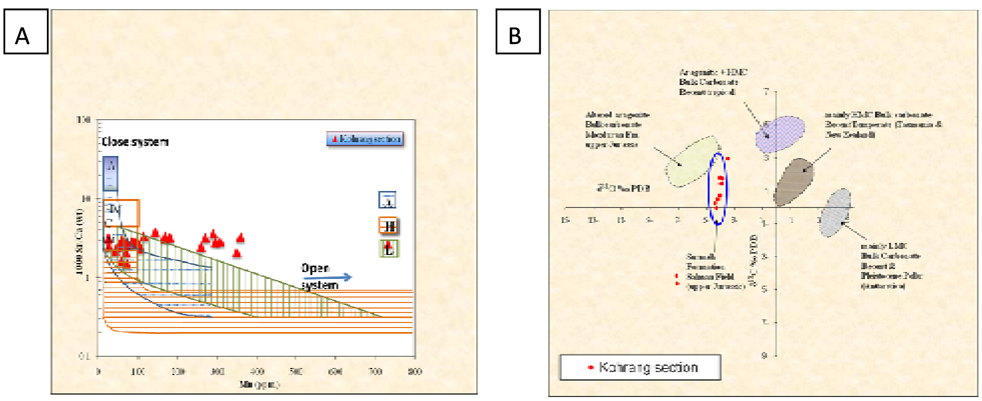

Fig. 2. (A) Mn and Sr/Ca variations in the Surmeh carbonates. This trend shows that these carbonates were affected by marine phreatic fluids in a closed to semiclosed diagenetic system. (B) . Comparison of δ 18O and δ 13C values of the Surmeh carbonates with recent tropical bulk carbonate (Milliman and Muller, 1977), recent temperate bulk carbonates (Rao and Adabi, 1992), polar bulk carbonate (Adabi, 1996), Altered aragonite bulk carbonate Mozduran Formation (Adabi and Rao, 1991) and Surmeh carbonate in Salman Field (Mahmoodi, 2006).