MICROFACIAS E ESTUDO GEOQUÍMICO DA FORMAÇÃO DE DALICHAİ: UM ESTUDO DE CASO DE ALBORZ CENTRAL NA PROVÍNCIA DE SEMNO, NORTE DO IRÃ

MICROFACIES AND GEOCHEMICAL STUDY OF THE DALICHAİ FORMATION: A CASE STUDY OF CENTRAL ALBORZ IN SEMNAN PROVINCE, NORTHERN IRAN

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RESUMO

Os principais depósitos progressivos bajocianos são acúmulo marroquino e calcário cheio de amonites e outros fósseis marinhos que são chamados de 'Formação Dalichai' com 1420m de espessura. Há erosão e limites inconsistentes que distinguem a Formação Dalichai da Formação Shemshak. O limite das formações Dalichai e Lar é isoclino e graduado. A presença de foraminíferos bentônicos, brilhos de esponja e amonites na seção Sharaf alude à existência de marinhos rasos a profundos. Processos diagenéticos como cimentação, micritização, porosidade, acumulação, óxido de ferro e bioturbação são observados na Formação Dalichai. Os carbonatos nessa formação podem ter composição aragonítica primária de acordo com os estudos sobre elementos principais e secundários, isótopos de carbono e oxigênio, e desenhando esses valores uns contra os outros. Em tal condição, a diagênese não marinha influenciou principalmente os carbonatos. Ao comparar Sr/Ca e Mn, pode-se sugerir que um ambiente diagenético semi-fechado para aberto tenha impactos nos carbonatos. A Formação Dalichai e a Formação Lar podem identificar um limite em 1200m de espessura, uma vez que existem mudanças nos Sr/Ca, Sr/Na, Sr e isótopos de carbono e oxigênio a serem estudados. A temperatura do calcário da formação Dalichai foi calculada em 32,9 °C. Em relação à litologia e análise das microfacias da seção Sharaf, são especificadas três microfacias que aparecem como depósitos na rampa externa. Neste estudo, sugere-se que o modelo de rampa homoclinal seja utilizado para essa formação. A seção Sharaf da formação Dalichai envolve composição mineralógica aragonítica na qual a diagênese do enterro influenciou substancialmente.

Palavras-chave: *Microfacias; Formação Dalichai; Diagênese; Ambiente sedimentar; Elementos principais e secundários; Isótopos de oxigênio e carbono.*

ABSTRACT

Top Bajocian progressive deposits are marly accumulation and limestone filled with ammonites and other marine fossils that are called 'Dalichai formation' with 1420m in thickness. There are erosion and inconsistent boundary that distinct Dalichai formation from Shemshak formation. The boundary of Dalichai and Lar formations is isocline and graded. The presence of Benthic foraminifera, sponge sparkles, and ammonites in the Sharaf section alludes the existence of shallow to deep open marine. Such diagenetic processes as cementation, micritization, porosity, accumulation, iron oxide and bioturbation are observed in Dalichai formation. The carbonates in this formation could have primary aragonitic composition according to the studies on main and secondary elements, carbon and oxygen isotopes, and drawing these values against each other. In such condition, non-marine diagenesis influenced the carbonates mostly. By comparing Sr/Ca and Mn, a semi-closed to open diagenetic environment can be suggested to have impacts on carbonates. Dalichai formation and Lar formation can identify a boundary in 1200m thickness since there are changes in Sr/Ca, Sr/Na, Sr, and carbon and oxygen isotopes to study. Dalichai formation limestone temperature was calculated 32.9 °C. Regarding lithology and analysis of Sharaf section microfacies, three microfacies are specified that appear as deposits in outer ramp. In this study, the model of Homoclinal ramp is suggested to utilize for such formation. Sharaf section Dalichai Formation entails aragonitic mineralogy composition on which burial diagenesis has substantially influenced.

Keywords: *Microfacies; Dalichai Formation; Diagenesis; Sedimentary environment; Main and secondary elements; Oxygen and carbon isotopes.*

چکیده

نهشته‌های پیشرونده باژوسین بالایی از نوع انباشته‌های مارنی و سنگ‌آهک‌های مارنی حاوی آمونیت و دیگر سنگواره‌های دریایی می‌باشد که به آن‌ها سازند دلیچای گفته می‌شود. ضخامت این رسوبات در منطقه شرف 1420 متر می‌باشد. مرز سازند دلیچای با سازند شمشک به صورت ناپیوسته از نوع فرسایشی و با سازند لار به صورت تدریجی و هم شیب است. وجود فرامینیفر بنتیک، سوزن‌های اسفنج و آمونیت در برش شرف بیانگر یک محیط دریای باز کم عمق تا عمیق است. از فرایندهای دیاژنتیکی در این سازند می‌توان به سیمانی‌شدن، میکرایتی‌شدن، تخلخل، آشفته‌گی زیستی، تراکم، آهن‌دار شدن اشاره کرد. مطالعه عناصر اصلی و فرعی، ایزوتوپ‌های اکسیژن و کربن و ترسیم این مقادیر در مقابل یکدیگر، حاکی از این است که کربنات‌های سازند دلیچای دارای ترکیب اولیه آراگونیتی بوده و دیاژنز غیردریایی بیشترین تاثیر را روی آن‌ها گذاشته است. ترسیم نسبت Sr/Ca در مقابل Mn نشان می‌دهد که این کربنات‌ها تحت تاثیر یک محیط نیمه بسته تا باز دیاژنتیکی قرارگرفته‌اند. با استفاده از تغییرات Sr ، Sr/Na ، Sr/Ca و ایزوتوپ اکسیژن و کربن، مرز این سازند با سازند لار در ضخامت 1200 متری مشخص شده است. دمای محاسبه شده برای سنگ آهک‌های دلیچای در برش شرف برابر با 32/9 درجه سانتیگراد می‌باشد. مطالعات سنگشناسی و آنالیز رخساره‌ای در برش شرف منجر به شناسایی سه ریزرخساره شد که در محیط رسوبی رمپ خارجی نهشته شده‌اند. مدل پیشنهادی برای این سازند یک سیستم رمپ هوموکلاین می‌باشد. سازند دلیچای در این برش دارای ترکیب کانی‌شناسی آراگونیتی است و دیاژنز تدفینی بیشترین تاثیر را روی آن گذاشته است.

واژه های کلیدی: ریزرخساره‌ها، سازند دلیچای، دیاژنز، محیط رسوبی، عناصر اصلی و فرعی، ایزوتوپ‌های اکسیژن و کربن

1. INTRODUCTION

In northern areas of Alborz mountain, no eupelagic deposits of upper Bajocian, Callovian (Dalichai Formation) and Oxfordian deposits, and Kimmeridgian (Lar Formation) exist and the younger rocks of Jurassic period are directly placed on the older rocks Shemshak deposits. Therefore, the northern and southern areas of Alborz experienced different geographical features from the upper Bajocian era until the last days of the Jurassic period. In their study, Davoudzadeh and Schmidt (1984) stated that the sedimentary basin of the northern Alborz is literary the continued highs of Lesser Caucasus syncline which indicates no sign of Bajocian and Bathonian rocks. However, southern Alborz is abundant with these rocks in many areas. The south parts in Alborz mountain entail sequence of rocks rich with ammonites and some marly and shale limestone in the formation of stratigraphic units. Among these sandstones and herb shales, it can be observed the presence of Shemshak group as well as thick limestone of Lar Formation (Upper Jurassic). The first explanation regarding the breccia of this formation was proposed by Erni (1931), discussing the signs of Bathonian ammonites in them. Later, Erni's suggested breccia was later reviewed by Steiger (1966) that lead the reviewed breccia to investigation by the 12th Iranian Committee of Stratigraphy and

announced it as an official stratum unit of middle Jurassic of Alborz mountain. This formation is known to have organized layer of marly limestone and limestone sand along with some layers of marly shale and ammonite fossils including *Oppelia* and *Parkinsonia* (Darvishzadeh, 2004) (Figure 6).

2. DEVELOPMENT

2.1. Geographical location

A Sharaf section shows middle Jurassic sedimentary rocks that are considerably spread in the north of Gardaneh-ye Āhūān (A village in Semnan called Jam) and are extremely thick (Figure 3). Alavi-Naini (1972) investigated Jam district as well as a Sharaf section and prepared its geological map with a scale of 1:100000. Semnan-Damghan's main road leads to the Sharaf section. The study area is located between latitudes N 35° 56' 12.5" and longitudes E 53° 45' 51" (Figure 1).

2.2. Methodology

An appropriate geological section for performing the field studies is selected based on 1:100000 Jam map and analyzing the satellite photos. At first, the section was investigated in terms of geological and tectonic considerations to identify the upper and lower formation edge clearly and allow sampling to takes place. Sharaf section

contributed to sampling by providing 149 samples perpendicular to the layers. Meanwhile, such characteristics as apparent thickness, geographical features, layers contact, lithology types, and the direction and dip of the beds were also studied. 137 thin sections were collected from the Sharaf section and examined by an optical microscope. Adopting Dickson methodology (1965), it was attempted to identify calcite and dolomite separately by painting some of the sections with an Alizarian-red-s solution. In the current study, Dunham (1962) and Folk (1962) classification was employed for naming limestone. Identifying the facies and representing the sedimentary environment, Flugel (2010) model and the classification of Burchett and Wright (1992) were adopted by this study. After conducting a detailed study on the carbonate rocks, 50 of them were chosen for the elemental analysis. For specifying main as well as secondary elements, the rocks powders were analyzed by means of atomic absorption spectroscopy of Iranian Geological Organization geochemistry laboratories. The range of primary elements (Ca, Mg) and secondary elements (Na, Sr, Mn) are represented by percentages and ppm, respectively. 18 elemental analyzed powders samples were chosen and transferred to the Central Science Laboratory (CSL) of the University of Tasmania for analyzing oxygen and carbon isotope. The analysis included 15 mg of the sample powder that was exposed to phosphoric acid for 24 hours with a temperature of 25 centigrade. The aim was to evaluate the emission of CO₂ of each sample by means of a mass spectrometer (micromass, 602 D). The error value of isotope measurement was $\pm 0.001\%$. Samples combined oxygen and carbon isotope is shown with δ (delta) sign, expressed based on parts per thousand (per mil), and evaluated with respect to Pee Dee Blemnite (PDB) standard.

3. RESULTS AND DISCUSSION

3.1. Stratigraphy

Dalichai formation of Alborz mountain range contains limestone, marly and marl limestone, and some layers of shale and siltstone among them. A detrital discontinuity caused by a middle Cimmerian event on siliciclastic deposits of Shemshak Formation companions this sequence. According to Nabavi, Jurassic sea depth slightly increased in the latest days of the Bathonian stage that gradually constituted more calcareous sediments. In Jam area (35 km Khavar, Semnan), the outcrop of Dalichai formation exists only in north Bactriana of Attari fault (Alborz areas)

(Figure 2) (Alavi-Naini, 1972). Sharaf mountain Dalichai formation establishes the alternates of olive-grey marls (Figure 5) and marly and sometimes nodular limestone with 1420m of thickness. This formation is identified by the fine nature of the rocks with a specified erosion in topography and a lower dip comparing to Lar Formation (Figure 3).

3.1.1. Dalichai Formation petrology in Sharaf mountain (Thickness=1420m) (Figure 7)

- Thin to medium limestone in 29m thickness of the layers
- Micro conglomerate in 23m thickness
- Alternate of thin layer limestone with grey to olive shales in 256m thickness.
- Medium layer limestone with shale and marl interlayers in 279m thickness
- Alternate of thin to medium layer limestone with grey shale in 768m thickness
- Thick to massive chert limestone (Lar) in 65 thick

3.2. Microfacies and sedimentary environment

Generally, the shallow open marine is located under the waves power line and in the middle ramp. Besides, the presence of polds is observable in more shallow parts. These polds are smaller in size by comparing to those exist in the lagoon environment. Since these species are widely spread across the globe along with an almost uniform condition for them, open marine stratigraphy is of vital importance. Deep open marine location is under the diluvial waves line and in the outer ramp.

Figure 4. Limestone layers of Sharaf section

Figure 5. Dalichai Formation Olive marl of Sharaf

Figure 6. Dalichai Formation ammonites of Sharaf section

3.2.1. Microfacies of Sharaf section

3.2.1.1. Microfacies of the shallow marine environment (A)

1. A₁ Sandy wackstone:

The microfacies groundmass is entirely constructed with micrites along with quartz grains (Figure 8.A).

2. A₂ Bioclast Sponge Spicules mudstone to wackstone:

Allochem presence is shallow in this microfacies and shaped like sponge spicules with prominent longitudinal and latitudinal sections. Most of the sponge sparkles are formed with silica. There are recognizable stylolite and iron paths in this microfacies, along with a noticeable surface fracture (Figure 8.B).

3.2.1.2 Deep open marine environment microfacies:

3. B Mudstone:

Allochem presence is significantly small (lower than 10%), and the groundmass is fully filled with micrites (Figure 8.C).

3.2.2. Sedimentary environment of the Dalichai Formation in the study section

Quiet environment index with no specific turbulences along with temperate hydrodynamic energy of deep marine and average salinity include a considerable mass of micrites with fine texture, a bivalve thin layer, sponge sparkles, and benthic and pelagic foraminifera, and the absence of sedimentary structures (Casovic *et al.*, 2004; Flugel, 2010). Such a condition locates on the outer ramp.

Thus, the microfacies with mud-supported groundmass, benthic and some pelagic foraminifera, bivalve layers, sponge sparkles, and no coarse skeleton particles can be related to shallow to deep open marine. The anaerobic and low oxygen condition has resulted in forming the

sponge sparkles. A carbonate ramp system can be regarded for Dalichai Formation microfacies of Sharaf section by studying the microfacies and the areas of formation, their gradually changes and the absence of such indexes as great barrier reefs, slip and failure structures, calci-turbidite structures, and pisolites and oncoids that are gradually found in carbonate ramps.

Dalichai Formation type of Sharaf section is a low slip carbonate ramp (Homoclinal) that has a continued shoreline to basin glaciis, regarding the comparison between the found microfacies and Wilson (1975) and Flugel (2010) standards and the studies on tectonic and stratigraphy conditions of Dalichai Formation.

3.3. Diagenetic processes of Sharaf section Dalichai Formation

3.3.1 Cementation

Diagenetic mainly carries out the cementation effort in which closed cavities become over-saturated by a high amount of flows. Analyzed Dalichai Formation samples by petrography studies indicate that sparrycalcitecement occurs rarely that all samples composition shows homogeneous micrites. In this texture, skeleton particles are appropriately dispersed. Sharaf section cementation process entails mostly the micrites groundmass and shows no cement textures. Only a few of the early samples were constructed with cement (Figure 9). Sharaf section fails to vary in different types of cement and only entails equant, block, and veined cement.

3.3.2 Mechanical Compaction:

The mechanical compaction is easily observed in the Sharaf section due to a low allochem gathering and the presence of mud-supported fabrics. Such compactness is not of vital concern regarding the history of breccia diagenetic.

3.3.3 Chemical Compaction

With an increase in grains and sediment solubility that can result in burden pressure or tectonic stresses, chemical compaction or pressure dissolution occurs (Adabi, 1996). Following this physical compaction, the exposure of chemical compaction provides to the sediments. They can be identified, then, by the pressure solution, stylolite formation, and joint solution that indicates some fractures. Besides, irregular

stylolite of different structures is observable in Dalichai formation (Figure 10.B). Calcite vein cement paintings explain the iron calcite presence in Dalichai Formation calcite veins. Since the veins cross the texture and components of the rock, they can have a tectonic origin. In some cases, these veins are cut by a stylolite that may be as the result of burial diagenesis of the diagenetic Dalichai Formation history. Some small scale and multistages fractures are approximately found (Figure 10.A, Figure 10.C).

3.3.4 Porosity

It is defined as a totally empty space ratio over the total volume of rock (Choquette & Pray, 1970). Porosity beginning of a groundmass may take place diagenesis. Sharaf section porosity shows up itself with cavity, intra-grains, inter-grains, channel, and fracture (Figure 11).

3.3.5 Silicification

It is a standard diagenetic process that happens for unsialic sedimentaries with little or sporadic effects (Hesse, 1989., Tucker, 2001). Over-saturated sialic pore flow is required for carbonate sedimentary silification that can be occurred in any diagenesis stages, including primary, middle, delayed (Tucker, 2001). Each breccia silification displays silicious existence on sponge sparkles, as a substitute for echinoderms fossils, or in the groundmass (Figure 12.C).

3.3.6 Iron Oxide

Carbonate sedimentary iron oxide is a diagenetic process. Mostly stylolite lines, solution veins, porous spaces, and/or in fossil rocks are the hosts for iron components. Iron oxide occurs widely and extensively fills empty spaces of inter-grains, intra-grains, stylolite lines, fractures, and sometimes solution veins of micrite groundmass (Figure 11.B).

3.3.7 Dolomitization

Dolomite is a semi-stable mineral that substitutes its primary crystals with the next stable phases by a sequence process and in the burial and/or metamorphism period (Warren, 1989). Sharaf section dolomitization entails dolo-micrites and limited single crystal replacement (Figure 12.A, Figure 12.B).

3.4 Geochemical analysis

Argonite, high magnesian calcite (Shallow marine and tropical climate), and low magnesian

calcite (Deep and cold marine) are the main minerals of marine carbonates. According to some studies (Veizer, 1983, Rao, 1996), the minerals solution Ca and Mg, salinity level, and pressure CO₂ can be changed by exposing to temperature changes. Besides, unstable argonite minerals and high magnesian calcite transfers to a stable diagenetic low magnesium calcite under the influence of time and diagenetic processes. In this definition, carbonates' primary mineralogy is a complicated task.

3.4.1. Primary mineralogy of Dalichai Formation

3.4.1.1 Main and secondary elements

Strontium

Sr changes of bulk carbonate samples in new warm water regions are between 8000 to 10000 ppm per change (Millman, 1974). Temperate climate Bulk carbonate samples changes indicate 1600 to 5000 ppm (3250 ppm on average) (Rao and Adabi, 1992). The Sr amount in argonite is higher than the amount in calcite since Ca bigger cations (e.g., Sr, and Na) are preferably replaced in the argonite orthorhombic system. Almost 1000 ppm (maximum Sr amount) can be replaced in abiotic calcite system (Veizer, 1983).

Dalichai formation lime sample of the Sharaf section is the range of 183 ppm to 420 ppm. This amount is lower than that of recent. It may be as the result of diagenetic processes, particularly meteoric diagenesis (Adabi and Rao, 1991). Figure 13 categorizes Sr and Na amount based on the highest and the lowest rate, including recent argonite warm water with the highest Sr and Na amount, permian tasmanite subarctic limestone, recent temperate carbonate limestone, mozduran aragonite and gordon tasmania areas, Dalichai Maragheh limestone areas (Adabi and Abarghani, 2000), and cretaceous aged fahlian limestone. To specify tropical from non-tropical microfacies, Sr numbers are compared against Na numbers (Winefield *et al.*, 1996). As it is evident, Dalichai Formation lime samples are located in aragonite Dalichai Formation of Maraghe breccia due to the mineralogy of an identified composition (Figure 13).

Sodium

The amount of sodium in Dalichai Formation lime samples fluctuates from 742 to 1929 ppm. The level of sanitary, biochemical differentiation, kinetic evidence, mineralogy, and water depth are the factors of sodium centralization in recent carbonate sedimentary deposits (Millman 1974, Winefield *et al.*, 1996).

Sodium changes in recent aragonite deposits vary between 1500 ppm to 2700 ppm (Milliman, 1974, Adabi and Rao, 1991). Decreases of samples sodium against those of recent aragonite carbonates indicate non-marine diagenetic processes affects (Adabi, 2011).

Manganese

The range of manganese elements of the Dalichai Formation differs between 91 ppm to 749 ppm. Figure 14 illustrates compares Sr and Mn changes and shows that the samples are located in the Mozduran lime aragonite area. Mn diversities indicate diagenetic flow impacts. Mn and Fe amount of recent aragonite deposits display the numbers lower than 50 ppm (Milliman, 1974).

Sr/Ca ration

The diagenesis process in open/closed systems can be established based on the ration of Sr/Ca against Mn. In the study by Brand and Veizer (1981), it is identified the areas for aragonite diagenetic, high magnesium calcite (HMC), and low magnesium calcite (LMC) as illustrated in Figure 15.

In the case of water-rock interaction in open diagenesis systems, the amount of Sr/Ca meets reductions. Water-rock interactions are low in semi-closed, particularly closed, diagenetic systems that result in no obvious diagenesis Sr/Ca phases ratio compared to primary components. Generally, a decrease of magnesium in diagenetic calcite indicates a closed system. The chance of non-marine diagenesis of a semi-closed to open system is high for Dalichai Formation samples due to a low Mn amount and a decrease in Sr/Ca ration.

3.4.1.2 Oxygen and carbon isotopes

Considerable information regarding sedimentation environment temperature, diagenetic temperature, diagenesis processes in a diagenetic environment, salinity, alteration tendency, growth and/or sedimentation rate can be collected by analyzing oxygen 18 and carbon 13 isotopes (Marshall, and Ashton, 1980, Rao, 1996, Adabi *et al.*, 2016). Is doing so, carbonates of different areas can be distinguished. Dalichai limestone Oxygen 18 isotopes changes are between -2.49‰ to -4.86‰. This value ranges from +1.42‰ to +3.54‰ for carbon 13 isotopes of Dalichai limestone. Burial diagenesis has influenced the oxygen and carbon isotopes by imposing the changes (Figure 16). These modifications display a major and a minor change in oxygen and carbon isotopes, respectively

(Adabi, 2011).

Carbonate isotopes are created from the host lime, which can result in this minor change of carbonate isotope in the isotopically burial model. Besides, there is a lower isotope fractionation between carbon 13 isotope and carbon 12 isotopes by increasing temperature. It can be compared by the fractionation of oxygen 18 isotopes and oxygen 16 isotope that shows a higher value. Thus, there can observe an inclined linear tendency of oxygen and carbon values in burial diagenesis (Lohmann, 1988).

3.4.2. Temperature determination

Typically, the heaviest and the lightest oxygen isotope represents sedimentary environment temperature and diagenetic temperature, respectively (Adabi, 1996). Many equations suggest temperature determination based on oxygen isotope. This study has utilized the equation proposed by Anderson & Arthur (1983) as follows:

$$T^{\circ}\text{C} = 16.0 - 4.14(\delta_c - \delta_w) + 0.13(\delta_c - \delta_w)^2$$

In this formula, T represents temperature (centigrade), δ_c represents oxygen isotope content in 25 centigrade (PDB), and δ_w indicates marine oxygen isotope in the case of calcite accumulation (SMOW). The value of δ_w is considered zero for new marine; δ_c value differs in each period, but the period of Jurassic demands the value of -1.2‰ (Anderson & Arthur, 1983).

The temperature of the Dalichai Formation limestone of the Sharaf section has been calculated to be 32.9 centigrade. Regarding the previous explanations, these carbonates are subjected to non-marine diagenesis processes. Their oxygen and carbon isotopes are, thus, extracted, and they show a higher temperature against that of sedimentation processes.

Besides, the are large amounts of Fe (1400-9000 ppm) along with a little presence of Mn (91-749 ppm), and Na (742-1929 ppm) indicates the sedimentary environment unreal temperature which alludes its belongings to the burial very shallow environment.

3.4.3. Sr alterations against oxygen and carbon isotopes

Figures 12 and 13 illustrates Sr changes against oxygen and carbon isotopes, respectively. In both figures, the comparison of recent temperate bulk carbonate samples areas, upper Jurassic areas with aragonite mineralogy, as well as the areas of aragonite Mozduran formation,

Ordovician aragonite areas, and Gordon Tasmania aragonite formation areas are displayed (Adabi, 1996). As it is clear, most samples are located in aragonite mineralogy areas of Mozduran.

Carbonate isotopes changes of recent temperate areas show consistency due to the marine origin of the carbonates. Dalichai Formation carbonates expose small alteration and similar mineralogy composition that locates them in the Mozduran aragonites area (Adabi, 1996).

3.4.4. Mn changes against oxygen and carbon isotopes

Mn values of carbonate depend on redox and oxidation circumstances. In the case of the latter, only a few Mn elements can enter carbonate network. However, in redox conditions (half to full reactions), carbonate network accepts higher Mn values in itself (Adabi and Rao, 1991). The centralization of Mn is reduced by decreasing water depth and/or increasing the distance of shoreline. Most of the samples demonstrate the Mn value higher than 200 ppm, which suggests the presence of semi-aerobic or half redox reactions that dominated diagenetic environment. Comparing changes in oxygen isotope 18 and magnesium (Figure 19) of Dalichai Formation limestone implies that all samples are detected in the areas of upper Jurassic aragonite limestone of Mozduran formation and remote of Tasmania recent temperate areas limestone. This figure also reveals that oxygen 18 isotopes become lighter by occurring an increase in Mn value. This alludes alteration processes or non-marine diagenesis impacts.

Carbon 13 isotope can have constant changes in the areas where Mn values of temperate Tasmania limestone are changed. However, due to diagenetic processes, this isotope may vary in aragonite limestone of Mozduran Jurassic and Ordovician aragonite limestone of the Gordon group. Carbon 13 isotope also becomes lighter as the result of an increase in Ma due to non-marine diagenesis impacts (Adabi, 1996).

By drawing the changes in carbon 13 isotope and comparing them to Mn of carbonate samples, it can be mentioned that all samples are discovered in aragonite limestone of Mozduran formation upper Jurassic and are noticeably closed to $\delta^{13}C$ areas of aragonite marine of upper Jurassic due to a lower tendency of alteration (Figure 20).

3.4.5. Sodium changes against oxygen and carbon isotopes

Oxygen 18 isotope values of almost all Dalicahi formation samples are close to the areas of upper Jurassic aragonites with the least alteration tendency. This explains a little influence of non-marine diagenesis on these samples.

According to the values of Na against $\delta^{18}O$, it is clear that some samples of Dalichai Formation are spotted in Tasmania Gordon areas of aragonite limestone due to the same composition of mineralogy (Figure 21).

Carbon 13 isotope shows constant changes against carbonate sodium of recent temperate regions due to the marine nature of the carbonates. Regarding non-marine processes, Na values of Mozduran formation aragonitic carbonates meet a reduction by any decrease occurs in $\delta^{13}C$ (Adabi and Rao, 1991). Dalichai Formation carbonates are located in Mozduran aragonites due to their low tendency of alteration and identical mineralogy (Figure 22).

3.4.6. Secondary elements (Sr/Ca, Sr/Na, Sr) changes to distinguish boundaries of formations

An essential element in carbonates analysis is the Sr element. Some researchers, including Winefield *et al.* (1996), suggested the applicability of Sr/Na ratio to distinguish facies and boundaries of formations (Adabi and Asadi Mehmandosti, 2008). Lar and Dalichai Formations can readily be distinguished by considering Sr changes and their ratio to Ca and Na in the stratigraphy column. As Figure 23 illustrates, Sr values and Sr/Ca, Sr/Na changes are evident in Lar and Dalichai Formations boundary. This may prove the chemical composition differentiation of sea water when the formations establishment begins. Thus, both formations boundary can be evidently distinguished.

Obviously, both Lar and Dalichai Formations display different values of secondary elements since there is a dominance of physio-chemical changes in the environment. Besides, specified changes (i.e., shifts) exist in their boundary in 1200m thickness (Figure 23).

3.4.7. Carbon and oxygen isotopes

3.4.7.1. Oxygen 18 isotopes changes of Dalichai and Lar Formations

Drawing oxygen 18 changes against Lar and Dalichai Formations thickness expresses oxygen isotope changes in the boundary of both

formations. In Figure 24, it is revealed lower changes of oxygen isotope in Dalichai Formation, particularly Lar Formation boundary. The lowest value of oxygen 18 isotope is observed in Lar – Dalichai Formations boundary. Such changes resulted in a space between them. In the isotope analysis, it was attempted to utilize the samples with the lowest alterations (i.e., those samples that have kept the primary marine characteristics). Oxygen 18 isotopes substantial changes, particularly in two formations boundary, which can be as the result of metaoritic waters or burial diagenesis impacts.

3.4.7.2 Carbon 13 isotope changes of Lar and Dalichai Formations

Similar to oxygen 18 isotopes, changes in carbon 13 isotopes in the boundary of two formations are clearly identified. Lar Formation carries a lighter carbon isotope and shows higher fluctuations compared to Dalichai Formation. Figure 25 marks the constant changes in carbon 13 isotope in the stratigraphy column. And the carbon begins to have the lightest value in the Lar Formation boundary.

4. CONCLUSION

- Dalichai Formation considers being the first marine sedimentary of Alborz middle Jurassic with a particular outcrop in south regions. The deposits are formed in a marine environment. Dalichai marly rocks play a guidance role as a slightly green layer that can distinct the dark bottom layers with coals from the Lar Formation top rocks.
- Dalichai Formation thickness of the Sharaf section was estimated at 1420m. Any changes regarding the thickness of the Dalichai Formation in structural zone of central Alborz fail to follow a distinct procedure. It can be as the result of dominance of tectonic conditions over the region, the presence of a tensile phase, inconsistency of sedimentation, and bed rock conditions in the formation time.
- Dalichai Formation displays inconsistent existence on the siliciclastic formation of Shemshak with an erosion nature. Lar limestone formation meets the upper part of the Dalichai Formation, which is consistent and isoclinal. Dalichai top boundary with Lar Formation is where marly layers disappear, and chert layers emerge.
- Variety of diagenetic processes, including accumulation, stylolitization, cementation,

iron oxide, silification, dolomitization, and types of porosity, have imposed effects.

- Regarding microfacies researches, three microfacies have been identified for Sharaf section as follows:
Outer ramp micro facies:
C1 Sandy-Wackestone
C2 Bioclast Sponge Spicules mudstone to wackestone
D Mudstone
- The proposed model for this formation of the Sharaf section depends on microfacies types, the absence of great barrier reefs, slip and failure structures, calcsilturbidite structures, pisolites, and a Homoclinal ramp.
- Regarding the proposed model, the sedimentary environment of the Sharaf section is an open marine.
- Primary and secondary elements and isotopes analysis of the Dalichai Formation expresses the primary aragonitic mineralogy presence in the formation. By comparing oxygen and carbon isotopes, it can be mentioned a shallow burial diagenesis processes.
- It can be concluded the impacts of non-marine of a semi-closed to open environment on the carbonates according to the changes in secondary elements, particularly Sr/Ca against Mn, and the changes of $\delta^{18}O$ and $\delta^{13}C$ of the formation carbonates.
- In 1200m thickness, the boundary for Lar Formation and Dalichai Formation is evident that is as the result of physio-chemical water changes, diagenetic processes, and Sr/Na, Sr/Ca, and Sr changes. Besides, a shift occurs for oxygen and carbon isotopes in this thickness. This fact can prove the secondary elements changes of this boundary.
- Utilizing Arthur and Anderson's (1983) Equation, Dalichai Formation calculated temperature is 32.9 centigrade. Meteoric and burial types of processes have impacted the carbonates that resulted in carbon and oxygen extraction. Thus, temperature calculation shows a higher a higher number than the real one in time of sediment formation ($\delta_w = -1.2\text{‰}$).

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Figure 1. Location map pf the study area and the section studied.

Figure 2. Sharaf section (A) with a geological map of Jam with the scale of 1:100000 (Alavi-Naini and Hamed, 1972)

Figure 3. Sharaf mountain (southwest view)

(C). B Mudstone, Section 89

Figure 8. Microfacies of Dalichai Formation in Sharaf section

(A). Filler vein cement – Noraml light (PPL) – section 6

(B). Block cement filling a vein – polarized light (XPL) –section 5

Figure 9. Dalichai Formation cement types of Sharaf section

(A). Small scale fractures – normal light (PPL) – section 47

(B). Styolite – Normal light (PPL) – section 108

(C). Crossed multistages fractures – Normal light (PPL) – section 47

Figure 10. Compaction types of Sharaf section

Figure 11. Porosity type of Sharaf section

Figure 12. Other diagenetic processes of Sharaf section

Figure 13. Na and Sr changes comparison in Dalichai Formation lime samples of Sharaf section
Regarding some limitations, aragonite mineralogy, and identical diagenetic processes, Dalichai Formation lime samples are located in the area of Maraghe formation (Adabi and Abarghani, 2002)

Figure 14. Na and Sr changes comparison in Dalichai Formation lime samples of Sharaf section Regarding the same aragonite primary mineralogy, samples are located in Mozduran formation. Dalichai Formation limestone of Maraghe shows a high amount of Mn due to the diagenetic flow impacts and the tendency of alteration.

Figure 15. Sharaf section ($\frac{Sr}{Ca}$) changes processes against Mn Dalichai Formation lime samples are influenced by diagenetic processes of a semi-closed to open system, regarding the established areas by Brand and Veizer (1981)

Figure 16. Sharaf section Dalichai Formation diagram of $\delta^{18}O$ against $\delta^{13}C$
The inclined carbon and oxygen tendency indicates shallow burial diagenesis

Figure 17. Changes of $\delta^{18}O$ against Sr values of Dalichai Formation of Sharaf section. Most of the samples are located in the areas of aragonite mineralogy and many others near upper Jurassic aragonite areas

Figure 18. Changes of Sr values against $\delta^{13}C$ of Dalichai Formation of Sharaf section. The changes are insignificant due to the weak impacts of Diagenesis processes on carbon isotopes

Figure 19. Changes in $\delta^{18}O$ against Mn of Dalichai Formation of Sharaf section
As it is evident, most samples are located in primary aragonite mineralogy composition by comparing to the proposed areas of recent temperate carbonates, Gordon aragonite limestone of Tasmania (Rao, 1990), and aragonite carbonate areas of Mozduran formation upper Jurassic (Adabi, 1996)

Figure 20. changes in $\delta^{13}C$ against Mn values of Sharaf section Dalichai Formation
Drawings on Mozduran formation limestone areas, carbonate samples areas of recent temperate regions, Tasmania Gordon aragonite areas, upper Jurassic marine aragonites, and Ordovician aragonite marine can allude the similarity of Mn value changes of both aragonite samples of Dalichai Formation and marine aragonites of upper Jurassic that show no relationship to any changes of $\delta^{13}C$

Figure 21. Changes in $\delta^{18}O$ against Na of Dalichai Formation of Sharaf section
It draws Dalichai Formation samples in comparison with proposed carbonates of recent temperate areas, Tasmania Gordon aragonitic limestone (Rao, 1990), and upper Jurassic areas of aragonitic carbonates (Adabi, 1996). As it is evident, most samples are located in aragonites areas of Mozduran upper Jurassic and primary aragonitic mineralogy of Tasmania Gordon.

Figure 22. Changes in $\delta^{13}C$ against Na of Dalichai Formation of Sharaf section
It draws Mozduran formation limestone, recent temperate carbonate samples, Gordon Tasmania aragonitic samples, and established areas of marine aragonites of upper Jurassic and Ordovician. Dalichai Formation carbonates are displayed to be in Mozduran aragonites due to a low alteration tendency and identical composition of mineralogy.

Figure 23. Changes of Sr (A), Sr/Ca (B), and Sr/Na (C). Elements changes in 1200m thickness are sharp.

Figure 24. Oxygen 18 isotope changes in Dalichai and Lar Formations
Obviously, oxygen isotope suggests different values for both Lar and Dalichai Formations. The boundary for both formations is determine based on the lower value of oxygen isotope of Lar Formation compared with that of Dalichai Formation

Figure 25. Carbon 13 isotopes for both Lar and Dalichai Formations as regards lighter isotopes of carbon in thickness 1200m, Dalichai Formation establishes a boundary that distinct it from Lar Formation. This carbon isotope shift may be the result of non-marine diagenesis processes.