

## **Depositional environment and sequence stratigraphy of the members 3, 4 and 5 of the Mila Formation in the Hasanak-dar, Central Alborz**

**H.K.Hosseini<sup>\*1</sup>, Y.Lasemi<sup>2</sup>, D.Jahani<sup>3</sup>**

1)Hanieh\_karimi@yahoo.com 2)ylasemi@yahoo.com 3)jjahani\_davood@yahoo.com

### **Abstract**

*The 3, 4 and 5 stratigraphic members of the Mila Formation (middle Cambrian to late Ordovician age) has about 120 m thickness in the Hasanak-dar section and mainly is characterized by mixed carbonate and clastic successions. Field and microscopic observations have been carried out on the Mila Formation in order to recognize the sedimentary environments. The following investigations represent the member three is comprised of shallow marine mixed carbonate and clastic facies, the member four is attributed by continental calciturbidite sediments and the member five is mainly marked by a set of deep sea clastic facies. In term of sequence stratigraphy, the three significant third-order cycles have been identified on the 3, 4 and 5 member of the Mila Formation.*

**Key words:** Ordovician; Hasanak-dar section; Mila Formation; Cambrian.

### **Introduction**

The study area is located in middle part of Alborz Mountains, northern Iran, 55 km North West of Karaj city, overlooking Hasanak-dar village. The Mila Formation type section is situated at Mila Kuh, about 230 km north east of Tehran (Stöcklin et al., 1964), though it has subdivided to five members ranging in age from Early Cambrian to Ordovician. This study focused on analysis the facies, sedimentary environment, parasequences and sequences of member's number 3, 4 and 5 of Mila Formation in the central parts of Alborz Mountains.

In the first stage, maps with the scale of 1/100000 from outcrops in member 3, 4 and 5 of Mila Formation was produced. Then, sample was taken from different sediment layers and study microscopically. Based on microscopic analyses, sediment facies were named using Dunham method (Dunham 1962) and for clastic using Folk method (Folk 1974) the maximum matrix size is considered 0.06 mm, beside this the sediment model of area were specified. Finally, With the purpose of studying the stratigraphy of Mila Formation sediments tried to using by the sequence stratigraphy method (Van Wagner and colleagues 1990) for the Hasanak-dar outcropped section

### **Stratigraphy**

In Hasanak-dar section the lower part of Mila Formation is conformable with the Top quartzite of Lalun Formation and top of Mila Formation is unconformably overlain by quartzite forming the lower part of the dominantly calcareous Late Devonian to Early carboniferous Jeirud Formation (Alsharhan 1997). In this section Member 3, 4 and 5 of Mila Formation is about 120 m, which could be described from base to top as follow:

a. **Member 3:** is about 34.5 meters, including alternating medium to thick layer of gray limestone comprising skeletal grains such as trilobite, echinoid and brachiopods, and non-skeletal such as oncoïd in the company of gray glauconite sandstone and dark gray shale.

- b. **Member 4:** Thickness is 47.5 meters that consists of alternation of medium to thick-bedded grayish green glauconite sandstone and pink massive fossiliferous conglomerates.
- c. **Member 5:** it is about 38 meters, including alternating gray to black laminated shale and pencil shale with thin layer sandstone and limestone. There are rejected out basalt masses between shale layers.

### **Discussion**

Member 3 consists of two main different sediments: carbonate and clastic.

#### **Carbonate Microfacies**

There are six carbonate microfacies in the 3<sup>rd</sup> member of Mila Formation in the studied surface section those are as follow:

##### **MF1: Silty Mudstone (Lagoon)**

This microfacies consists of silt size quarts, mica and opaque minerals in a muddy matrix. It is thin-laminated.

This microfacies is belonging to lagoon based on the grain size, frequent muddy matrix and no fossil contents.

##### **MF2: Silty skeletal peloidal wackestone (Lagoon)**

The samples shows peloids (9-12%), silt size quarts (8%) and scattered skeletal debris such as echinoids and trilobites in micrite matrix. Peloids are mostly dolomitized. They are showing a low-energy environment in shallow carbonate platform such as lagoon, besides there are transported skeletal grains into the lagoon from adjacent open marine area, principally during storms.

##### **MF3: Silty skeletal packstone (Lagoon)**

This microfacies consists of skeletal grains such as Echinoid (10%) and trilobite (6%), also non-skeletal grains such as sand size quartz (15%) in mud-supported fabric. In addition microbial filaments are common in this microfacies. The presence of marine skeletal grains and non-skeletal grains in micritic matrix supports the restricted to semi restricted lagoon environment.

##### **MF4: Echinoderm grainstone (Shoal)**

The main aspect of this microfacies is the profusion of echinoids or trilobite. Other constituent grains are sand size quartz particles. Grainstone is the most common texture in this facies. Based on the ingredients and its texture, this facies should be deposited in a high energy environment like shoal.

##### **MF5: Echinoderm grainstone (Shoal)**

This facies consist of skeletal grains, rounded intraclasts (averagely about 10%) and some sand-sized quartz particles. The majority of skeletal grains are echinoids; however there are also brachiopods and trilobites in this facies. This microfacies is affirmed to be deposited in a shoal environment.

##### **MF6: Oncoid Skeletal grainstone (Shoal)**

This microfacies consist of oncoïd (up to 35%), skeletal debris, glauconite and sand size quartz particles. Common oncoïds nucleuses are trilobites and their sizes are around 0.5 mm. To be aware of forming oncoïds in high energy environments, plus roundness of these non skeletal grains and absence of evaporate minerals confirm the high energy environment such as shoal for this microfacies.

### **Clastic Lithofacies**

There are 4 lithofacies in the 3<sup>rd</sup> member of Mila Formation in the studied surface section those are as follow:

#### **F1: Sublithic Arenite (Beach)**

This lithofacies is comprised about 4% of the total thickness in clastic part of the studied section. The facies is consisting of quartz (averagely about 65%), mostly with straight darkness, lithoclasts (averagely about 10%) and k-feldspars (averagely about 2%) within calcite cements. The majority of lithoclasts are chert and calcite particles. Features like well sorting and sub-roundness of grains in this facies signify a shallow marine environment possibly generated throughout low down sea level time.

#### **F2: Calcilithite (Coastal plain)**

The common lithics are calcitic particles in this facies, which are mostly composed of echinoid, trilobites and chert grains. Immaturity of sediment in this lithofacies signifies that the facies might be deposited in a coastal plain and could be show a short time progradation.

#### **F3: Chert arenite (Beach)**

This facies consist of chert (up to 70%), glauconite (averagely 5-10%) and mature sub rounded fine-grained quartz particles. The features affirm that this facies could be deposited in a shallow marine environment during low down sea level period of time.

#### **F4: Shale**

In this member green shales are interbedded by thinly bedded limestone and sandstone. Fossils and trace fossils are generally absent.

### **Member 4**

There are three lithofacies in the 4<sup>th</sup> member of Mila Formation in the studied surface section those are as follow:

#### **F1: Oligomictic conglomerate (Braided river)**

This lithofacies is identifiable by its pink color and its large grains, which averagely are about 2 cm, in the outcrop. The source of a large amount of clasts in this lithofacies is reworked grains of member 3. This lithofacies show fining upward graded bedding. All results are specifying of a braided river environment.

#### **F2: Glauconitic sub lithic arenite (Coastal environment)**

This lithofacies consist of glauconite (20%), mono-crystalline quartz, chert and very fine-grained serisite in calcite cement. well sorting and roundness of grains demonstrating a high energy coastal environment.

#### **F3: Caletithite / Glauconitic Calcilithite (Coastal)**

This lithofacies consist of carbonate clasts, mostly echinoid, trilobite and brachiopods and glauconite, quartz and chert grains (averagely 10%). Glauconite and quartz grains point out a coastal environment for this facies.

### **Member 5**

There are four lithofacies and just one microfacies in the 5<sup>th</sup> member of Mila Formation in the studied surface section those are as follow:

#### **MF1: Silty skeletal wackestone (Open marine)**

This microfacies consist of trilobite (15%) and echinoid (10%) goes with micrite matrix. Based on the allochems and presence of bioturbation in this facies, it should be formed in a low energy environment such as open marine.

**F1: Oligomictic conglomerate (Open marine)**

This lithofacies specifies by its gray color and averagely 1-2 cm grains size in the outcrops. This lithofacies demonstrates fining upward graded beddings. All of the features are indicating an open marine environment for such turbidite sediments.

**F2: Calcilithite (Open marine)**

This lithofacies is composed of bioclast such as echinoids, trilobites and brachiopods in addition to sub rounded quartz confined by calcite cements. This lithofacies shows a fining upward sequence that demonstrates turbidity sediments of open marine.

**F3: Glauconitic sedarenite (Open marine)**

This lithofacies consist of bioclasts such as Echinoid, Trilobite and Brachiopod beside this fine to medium sub rounded mono-crystalline quartz are recognized in calcite cement. This lithofacies show graded bedding that shows turbidities in open marine.

**F4: Shale (Open marine)**

This lithofacies consist of colored shale such as green, gray and pink ones. Intercalation of thin laminated shale and fining upward sandstones demonstrates an incomplete Bouma cycle. Facies in the member's number 5 of Mila Formation are mainly terrigenous and just one thin carbonate facies have been identified. The terrigenous facies are including conglomerate, sandstone and shale facies which are encompass 5%, 20-25% and 60% of the stratigraphy column, respectively.

Field and microscopic scale studies showed that member's 5 of Mila Formation should be deposited in a deep sea environment. By reason of presenting graded bedding, incomplete Bouma cycles, sudden borders of sandstones and also carbonate conglomerates with dark laminated shales, the sediments might be reworked from shallow sedimentary environments to deep marine environment by turbidity currents. But the other members of Mila Formation contain of facies from the shallow marine environment and on a ramp platform.

Tectonic activities related to Paleotethys rifting in the beginning of Ordovician resulted to more steeping of basin and consequently deposition of member number 5 of Mila Formation in a deep marine environment. The basaltic mass founded in the dark laminated shales might be created during the rifting time.

**Sequence stratigraphy**

Each of genetically interrelated sequence in a facies belt, which is created in connection with sea level fluctuation, bearing a number of sedimentary cycles consist of shallowing upward parasequences sets. (Lasemi, 2001)

There are three sedimentary sequences in the member's number 3, 4 and 5 of Mila Formation in the Hasanak-dar outcropped section (Figure 1).

The first sequence is not complete and about 45 meters thickness. It is consist of the calcareous sandstones and shallow marine carbonate deposits (HST). Transgressive system tracts of this sequence is like Shahmirzad and Toye-darvar belong to upper part of member two of Mila Formation (Lasemi 2001), and top of this sequence is disconformity.

In this sequence, carbonate sediments indicated transgression unit and sandstones are point to regression unite these two unit show small-scale retrogradation cycles. The upper part of this sequence is not preserved due to erosion.

The second sequence thickness is about 47.5 m which is overlain by a disconformity on the first sequence. Transgressive glauconitic sub-lithic arenite followed by coarse grain calcilithite showed a disconformity before sedimentation of member four (Lasemi 2001)

This calcilithite tends to be sourced by reworked material from the underlying succession and may have formed during a fall in relative sea-level and high stand sea related to Paleotethys rifting. These sediments show fining upward and bioturbated glauconitic sandstone which indicated a maximum flooding surface and overlain by continental calcilithite which shows high stand system tract.

Thickness in the third sequence is about 37 meters and includes member 5 of Mila Formation. Lower part of this sequence is consisted of interbedded deep marine thin laminated dark shale and fining upward sandstones demonstrating an incomplete Bouma cycle. The upper part of this sequence consists of deep marine dark shale and cross-bedded sandstone, this part indicated HST. This sequence unconformably overlain by quartzite of Jairud Formation.

### **Conclusion**

Based on the mentioned research, we can extract these conclusions:

1 - 3<sup>rd</sup> member of Mila Formation mainly consist of calcareous facies and shallow marine clastics lithofacies which is dictated HST of a sequence. This member is shallow marine part of a ramp platform.

2- 4<sup>th</sup> member of Mila Formation mainly consist of continental calcilithite lithofacies and show a third order sequence.

3 - 5<sup>th</sup> member of Mila Formation in the Hasanak-dar section mainly consist of clastic lithofacies and show turbidite sediment of deep marine.

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