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MICROFACIES AND MORPHOTECTONIC OF THE TIRGAN FORMATION IN GHOROGH SYNCLINE (*North of Chenaran*)

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ABSTRACT

In this research, the Tirgan Formation in Ghorogh Syncline (north of Chenaran) with the thickness of 412 m in north flank and 251 m in south flank is studied. The Tirgan Formation in Ghorogh sectionsis included limestones, marlylimestones, shales and sandstones in lower parts of the formation. In these sections, there are impressions of echinoderms toxasteridae family, many of foraminifera from orbitolinidae family and also lots of calcareous algae that create facies variation along with other nonskeletal allochems. The study of sediment facies led to the recognition of four facies belts and six microscopic standard facies in the Tirgan Formation and shows the oscillation of sea level but totally it can be concluded that the basin was shallow and formed in the ramp platform. According to the evidence, the oolithic limestones and intercalated shales of the Tirgan Formation in south flank, Ghorogh Syncline are slided on the red sandstone of Shurijeh Formation as transition slides because of lubrication. These landslides are distinguished and formed (7times) because of the stresses which are done from the northern syncline to the south of Ghorogh valley and formed the current morphotectonic for the area. This phenomenon could name as decollement.

Contribution/ Originality: The paper's primary contribution is finding real thickness of Tirgan Formation in south flank Ghorogh Syncline. Morphotectonic studies show transitional slides of Tirgan Formation in Chenaran map (1:100000) wrongly named Shurijeh Formation while this research led to the corrected and these transitional slides named Tirgan Formation.

1. INTRODUCTION

The Kopet-Dagh sedimentary basin was formed in northeast Iran, southwestern Turkmenistan and north Afghanistan after the closure of the Paleotethys ocean following the Middle Triassic orogeny that involved the Iran and Turan plate (Alavi *et al.*, 1997); (Berberian and King, 1981); (Buryakovsky *et al.*, 2001); (Ruttner, 1991). The Kopet–Dagh basin formed in an extensional regime during the Early to Middle Jurassic (Garzanti and Gaetani, 2002). The Kopet-Dagh orogenic belt is an inverted basin (Allen *et al.*, 2003). Over 6000 m of sedimentary rocks ranging in age from Middle Jurassic to Miocene were deposited in the basin (Afshar, 1979). The Lower Cretaceous carbonates in the Kopet-Dagh basin constitutes one of the potential petroleum reservoirs.

The first geological investigations were carried out by griesbach in the eastern part of the Kopet-Dagh basin (Griesbach, 1887). The first detailed biostratigraphical and lithostratigraphic investigations were carried out by clapp and afshar harb (Clapp, 1940); (Afshar, 1969); (Afshar, 1979). The Cretaceous sequence in the Kopet-Dagh region of northeast Iran was studied by geologists of the National Iranian Oil Company (Niazi and Niazi, 1969). It appears to be complete there than in other parts of northern, central and eastern Iran. Lower Cretaceous deposits in the Kopet-Dagh are nominated as the Tirgan Formation that was suggested by afshar harb (Afshar, 1969). This formation is composed principally of ooid limestone, sandstones, dolomites in the base and marl, shale in the top and crops out along the Kopet-Dagh range. The Tirgan Formation is conformably overlain by shale of the Sarcheshmeh Formation and is conformably underlain by the siliciclastic red beds of the Shourijeh Formation.

In order to study of the Tirgan Formation, 2 sections in the Kopet-Dagh (Ghorogh Syncline) were surveyed (Fig.1). The thickness of these sections are 412 m and 251 m, these sections consist of limestone, marly limestone, shale and sandstone in lower parts of the formation (Fig. 2, 3). In these sections the benthic foraminiferal assemblages constitute the largest proportion of the total microfaunal content in terms of abundance, the calcareous algae identified also provide significant data for interpreting depositional environments and impressions of Echinoderms toxasteridae family with other skeletal and nonskeletal allochems were to analyze the facies to interpret the depositional environment. In south flank Ghorogh Syncline, oolithic limestones and intercalated shales of Tirgan Formation are slided on the red sandstone of Shurijeh Formation as transitional slides because of lubrication and formed decollement phenomenon (Aryaei *et al*., 2014).

2. METHODS OF STUDY

The study areas are located in 36º 50' 38" longitude and 59º 02' 38" latitude in north flank and 36º 49' 20" longitude and 59º 08' 06" latitude in south flank. Two sections of the Barremian/Lower Aptian were measured and sampled at north flankand south flank of Ghorogh Syncline (north of Chenaran). In this work, microfacies and morphotectonic of these sections are studied. Detailed sedimentological investigations have been carried out on two sections of Tirgan Formation in the north of Chenaran supported by the analysis of 200 thin-sections. The materials were obtained from sediments of the Tirgan Formation (Kopet-Dagh basin). Limestones have been investigated using thin sections. Carbonate rocks were classified according to Dunham's carbonate classification and Embry and Kloven (Dunham, 1962); (Embry and Klovan, 1971). The microfacies analyses are based on the schemes of Flugel (2004). Our interpretations include a classification of carbonates and microfacies types, as well as spatial reconstructions of depositional environments. Morphotectonic studies that are based on the Aryaei et al. led to the express really thickness of the Tirgan Formation in south flank of Ghorogh Syncline (Aryaei *et al*., 2014).

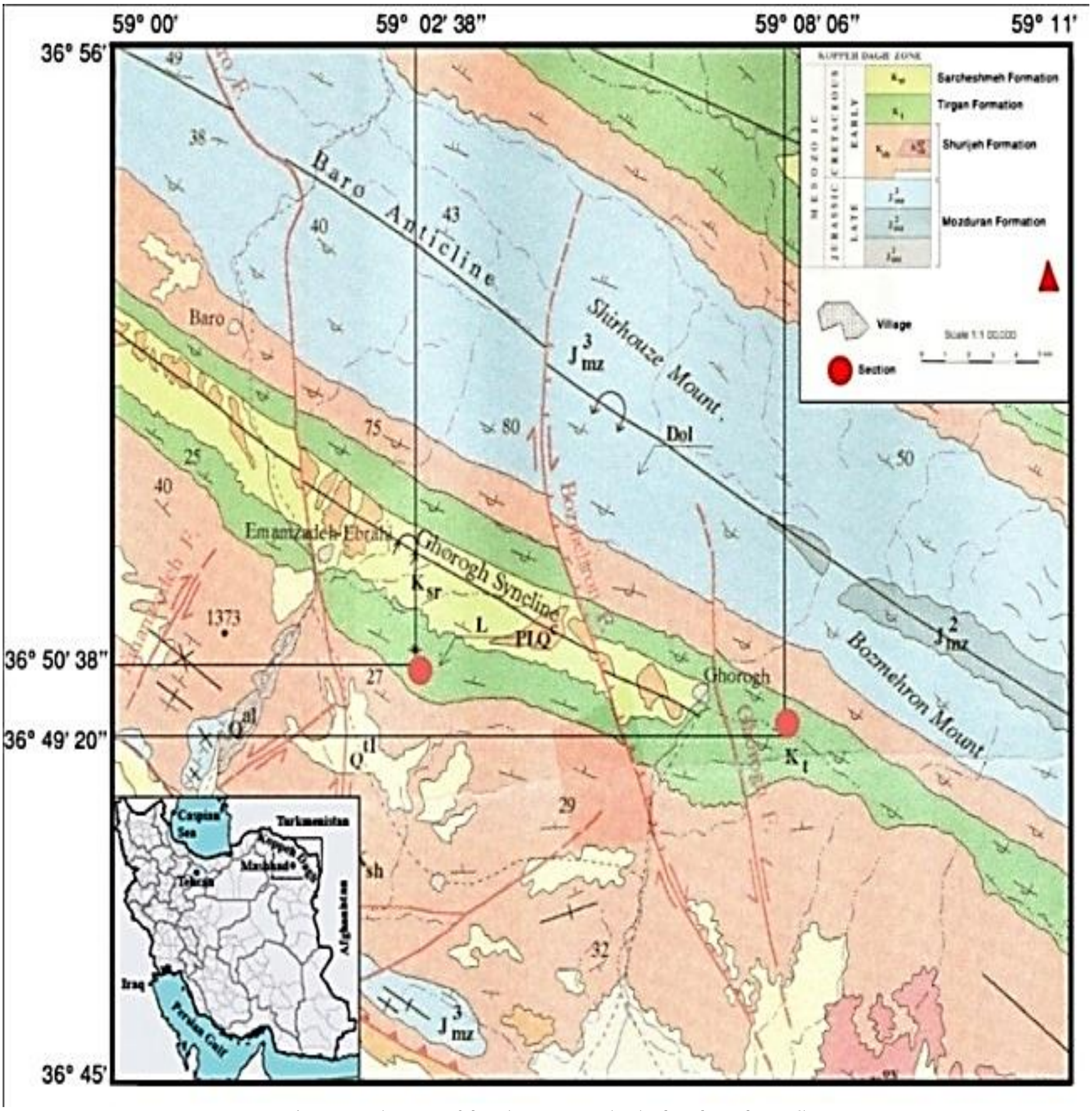

Fig-1. Location map of the Tirgan Formation in the Ghorogh Syncline

Source: Yavarmanesh (2017)

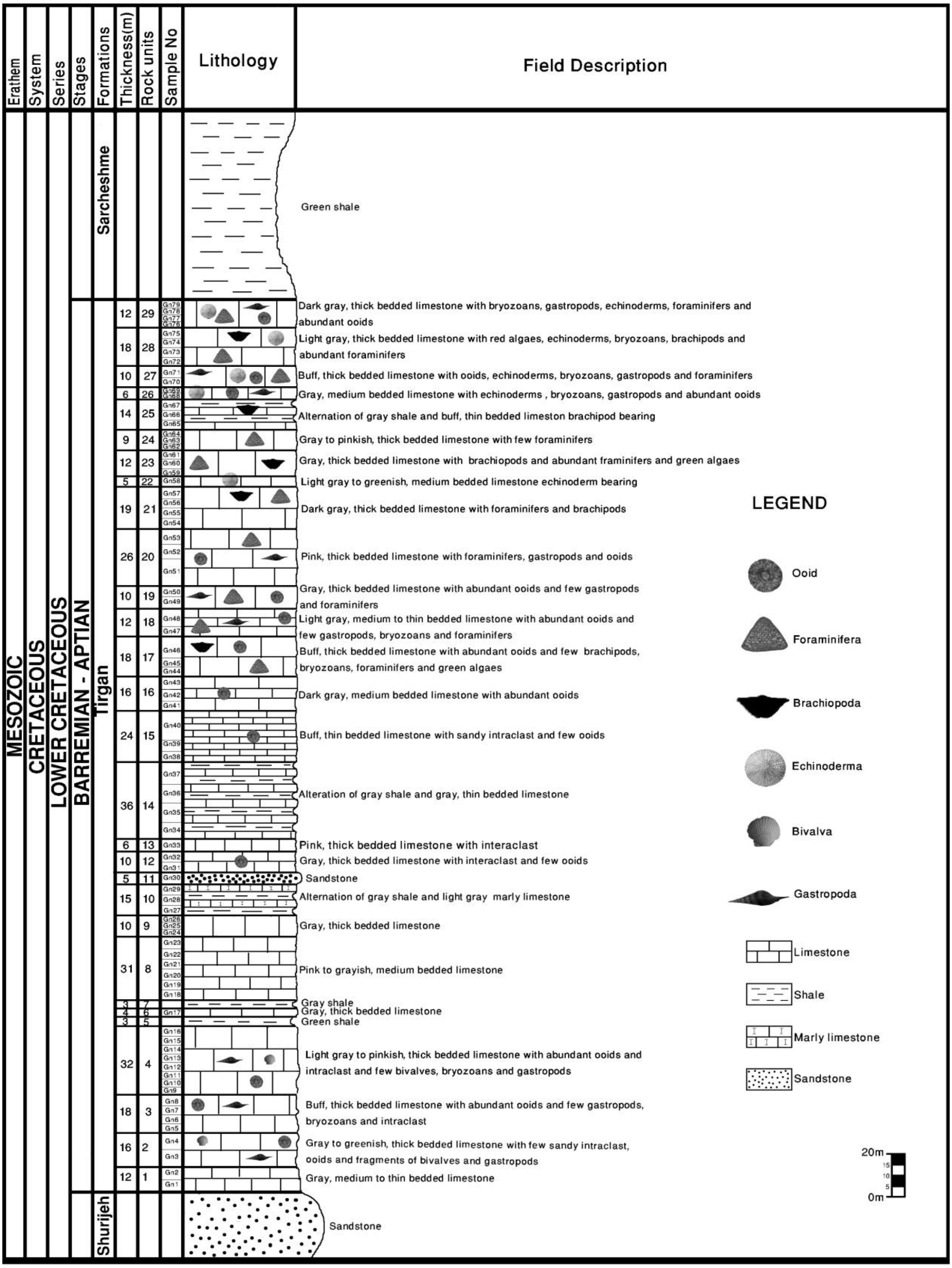

Fig-2. Stratigraphy of the Tirgan Formation in north flank of Ghorogh Syncline

Source: Yavarmanesh (2017)

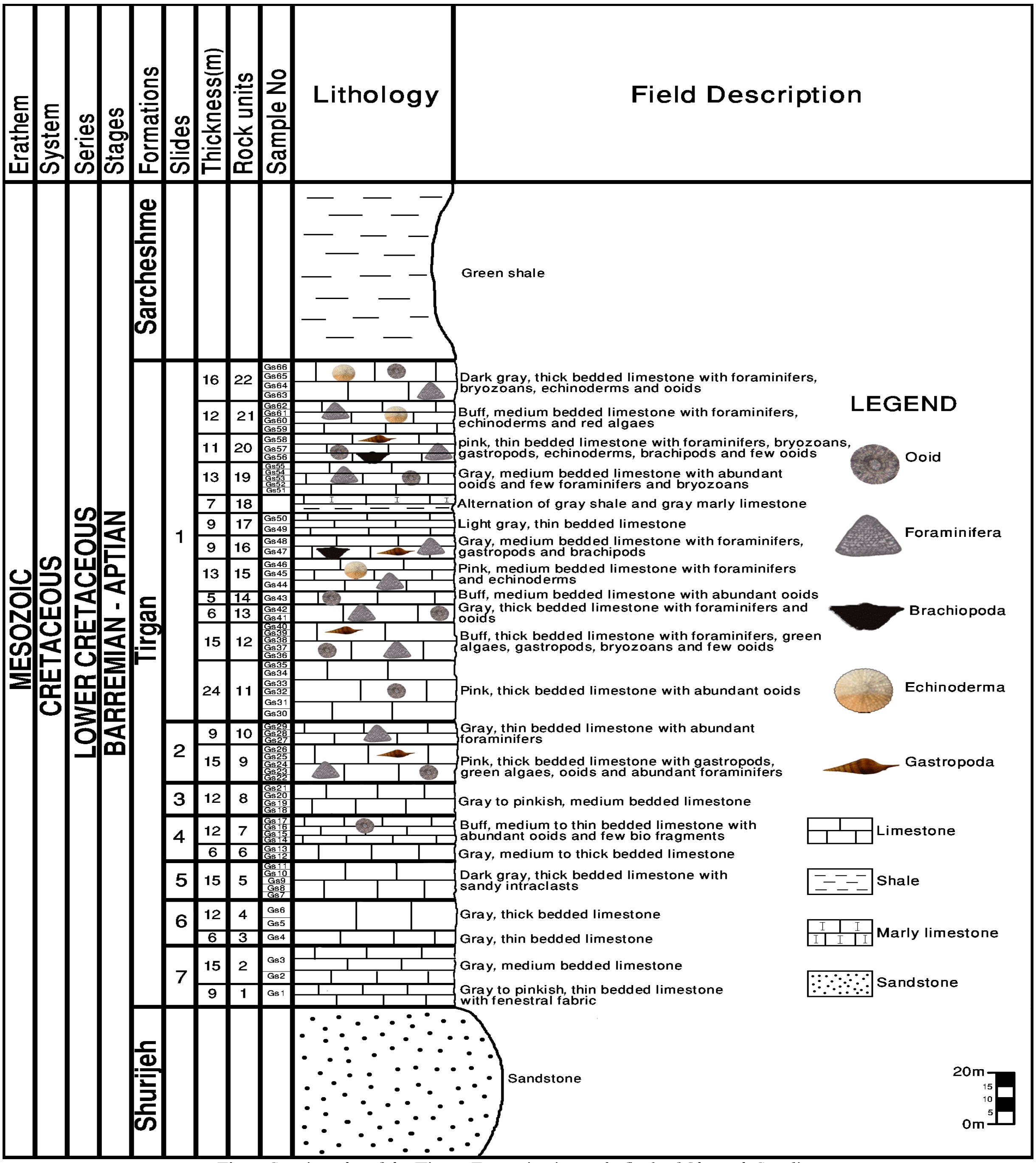

Fig-3. Stratigraphy of the Tirgan Formation in south flank of Ghorogh Syncline

Source: Yavarmanesh (2017)

3. RESULTS

In this research the microfacies and morphotectonic of the Tirgan Formation in Ghorogh Syncline is studied. The study of sediment facies led to the recognition of four facies belts and six microscopic standard facies in the Tirgan Formation (Figs. 4, 5, 6) and shows the oscillation of sea level but totally it can be concluded that the basin was shallow and formed in a ramp platform (Fig. 10) and Studies of morphotectonic led to the presentation the really thickness of Tirgan Formation in the south flank Ghorogh Syncline (Figs. 11, 12).

4. DISCUSSION

A) Depositional Facies Description and Interpretation

The strata of the Tirgan Formation are subdivided in to 9 carbonate microfacies (Fig. 4, 5) and 6 microscopic standard facies (SMF) (Fig. 6) that were recognized along 4 carbonate belts: tidal flat, lagoon, shoal and open marine. The determined microfacies are unfossiliferous mudstone (SMF 23), mudstone with fenestral fabric (SMF 21), foraminiferal packstone with abundant miliolids (SMF 18), strongly burrowed bioclastic wackestone (SMF 9), bioclastic packstone, brachiopod floatstone (SMF 12), ooid packstone, ooid grainstone (SMF 15) and bioclastic wackestone. Fig 4, 5 and 6 show the microscopic standard facies (SMF) and the microfacies types in both study sections.

Tidal Flat Belt (A)

Tidal flat belt includes two microfacies types: unfossiliferous mudstone (A1) and mudstone with fenestral fabric (A2).

Unfossiliferous mudstone (A1) contains limy mud and it is low in bioclasts, these strata are medium to thin bedded and gray in color (Figs. 4, 6).

Mudstone with fenestral fabric (A2), in this facies fenestral structures are well developed and filled with sparry calcite and without skeletal and non-skeletal fragments. The features of this facies indicate low energy shallow water and in outcrop, this facies are thin bedded, gray to pinkish in color (Figs. 4, 6).

Lagoon Belt (B)

Lagoon belt includes four microfacies types: foraminiferal packstone with abundant miliolids (B1), strongly burrowed bioclastic wackestone (B2), bioclastic packstone (B3) and brachiopod floatstone (B4)

Foraminiferal packstone with abundant miliolids (B1) contain abundant miliolids with few calcareous green algae, *orbitolina* and other benthic foraminifera in a field of mud, miliolids are very common in lagoonal environments (sometimes with elevated salinity) and show lowenergy shallow water, this facies is characterized by thin bedding and gray in color (Figs. 4, 6).

Strongly burrowed bioclastic wackestone (B2), fossils are fragments of gastropods, bryozoans, and benthic foraminifera, the matrix is fine-grained, rich in fossils represent the lagoonal center. Limestones with larger foraminifera and mollusks represent the shallow part of the lagoon. The composition of the gastropod fauna reflects changes from open-marine to more restricted conditions. These strata are thick bedded, have a buff color (Figs. 4, 6).

Bioclastic packstone (B3) include orbitolina, miliolids, echinoderms, bryozoans, gastropods and few ooids that transferred to lagoon environment, matrix consists of micrite, these strata are medium bedded, have a pink color and contain large skeletal crusts (Figs. 4, 5).

Brachiopod floatstone (B4) concentration of brachiopod shells resulting from high population density, the absence of bioerosion, abrasion and encrustation contradicts transport. Matrix is a lime mud. This facies is thick bedded and dark gray in color (Fig. 5, 6).

Shoal Belt (C)

Shoal belt includes two microfacies types: ooid packstone (C1) and ooid grainstone (C2)

Ooid packstone (C1) consists of limestone with abundantooids and few bryozoans and echinoderms in ooid cores. The ooid fabric is radial and concentric. Along the outcrop belt, these buff strata are medium bedded (Fig. 5).

Ooid grainstone (C2), the ooid grainstone facies consists of ooids. Their fabric is radial and concentric, there is less abundance of skeletal grains and intraclast, fossil fragments are in some of the ooid cores. Ooids are in sparry calcite. On the outcrop belt, the facies is thick bedded and pink in color (Fig. 5, 6).

Open Marine Belt (D)

Open marine belt includes bioclastic wackestones (D).

Bioclastic wackestones (D), skeletal grains in this facies group consist of orbitolina, brachiopods, echinoderms, red algae and few ooids, the matrix is a lime mudstone, ooid is indicant proximity this facies to shoal belt and show sedimentation is in the shallow open sea. These facies is thin bedded and light gray in color (Fig. 5).

Siliciclastic Facies

Siliciclastic facies includes sandstone facies (S) and shale facies (SH)

Sandstone facies (S), this facies located in the lower part of the section. The sandstone facies consist of quartz arenite that consist quartz (more than 95%) and the grain size ranges from fine to medium- grained sandstones. This facies is matur, in outcrop color is red with ripple mark.

Shale facies (SH), this facies is located in the upper part of the sections and consist of gray shale with thinly laminated that is alternation with mudstone and has a low abundance of fossils, containing few echinoderms, this facies is related to open marine environment.

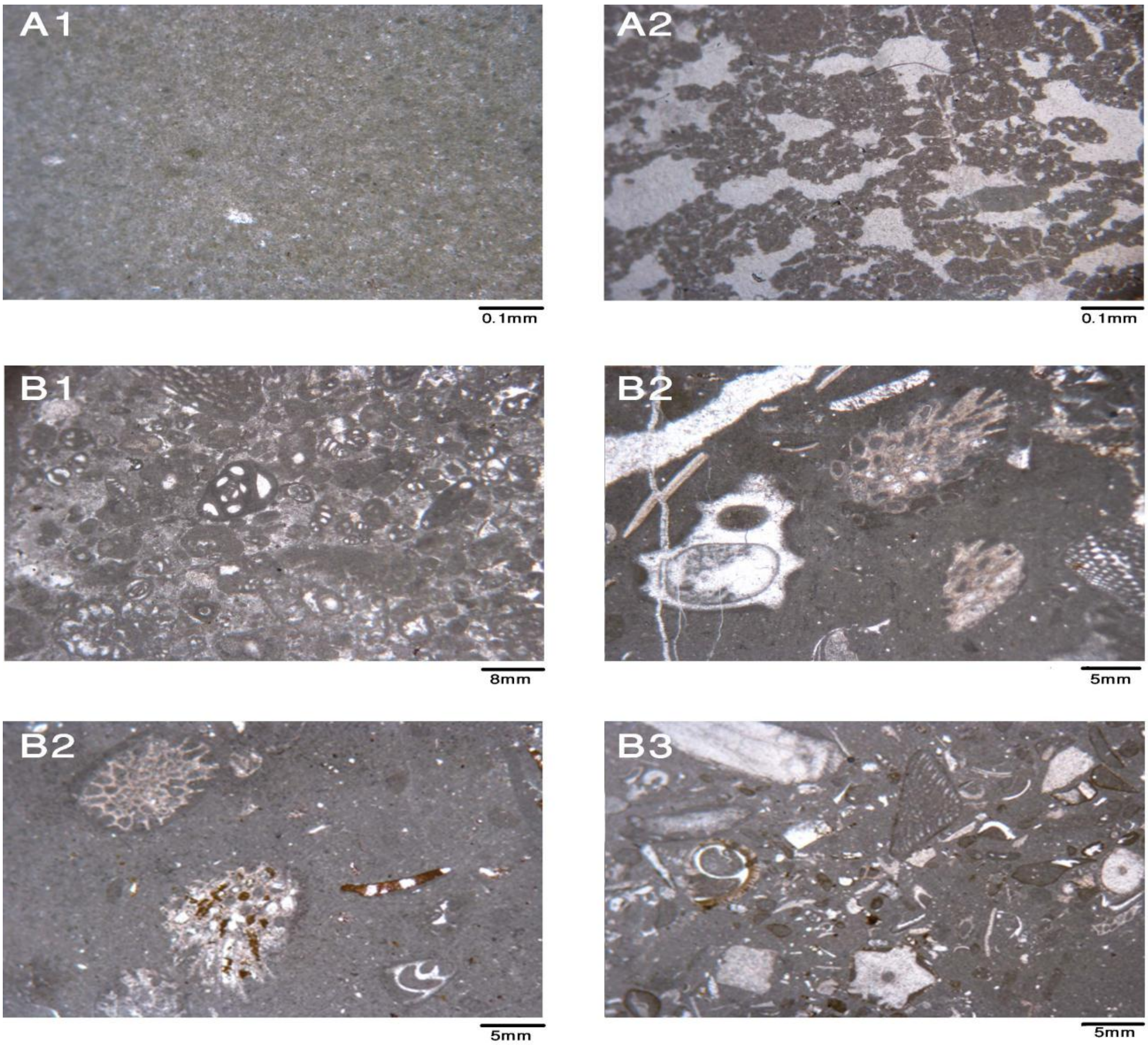

Fig-4. A1: Unfossiliferous mudstone, A2: Mudstone with fenestral fabric, B1: Foraminiferal packstone with abundant miliolids, B2: Strongly burrowed bioclastic wackestone, B3: Bioclastic packstone
Source: Yavarmanesh (2017)

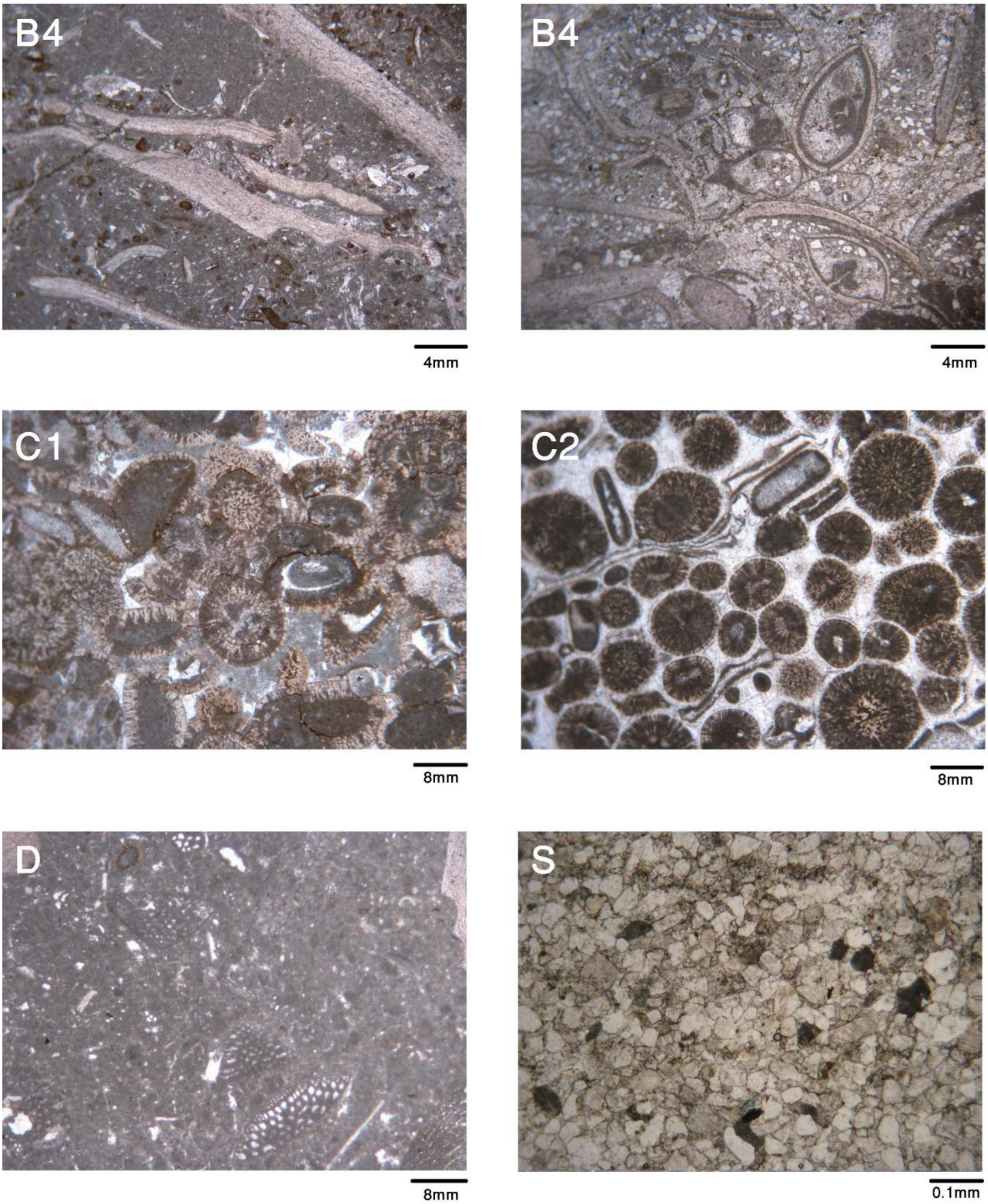

Fig-5. B4: Brachiopod floatstone, *C1*:Ooid packstone, C2: Ooid grainstone, D: Bioclastic wackestone, S: Sandstone (Quartz arenite)
Source: Yavarmanesh (2017)

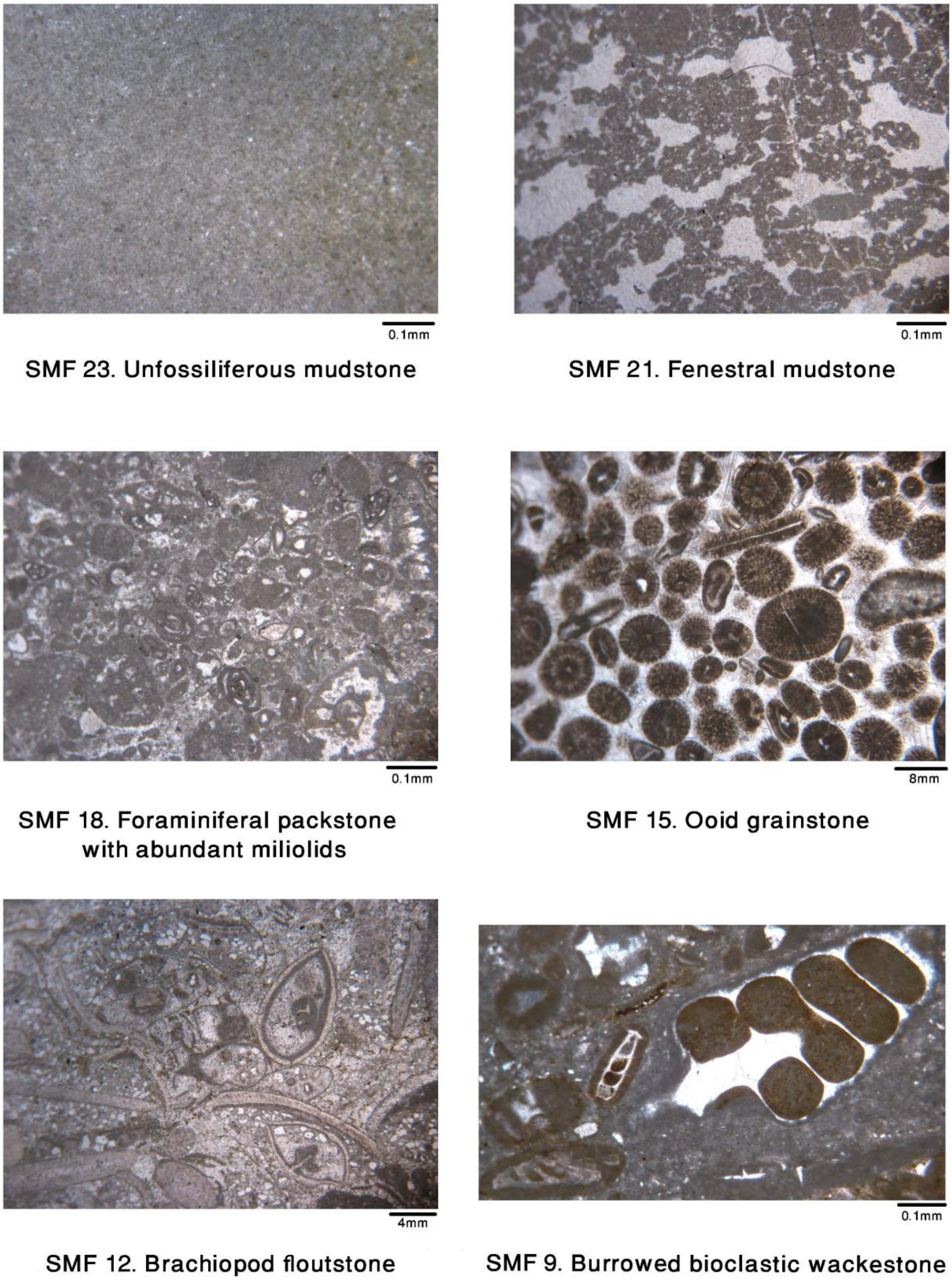

Fig-6. SMF types in Tirgan Formation (Ghorogh Syncline)

Source: Yavarmanesh (2017)

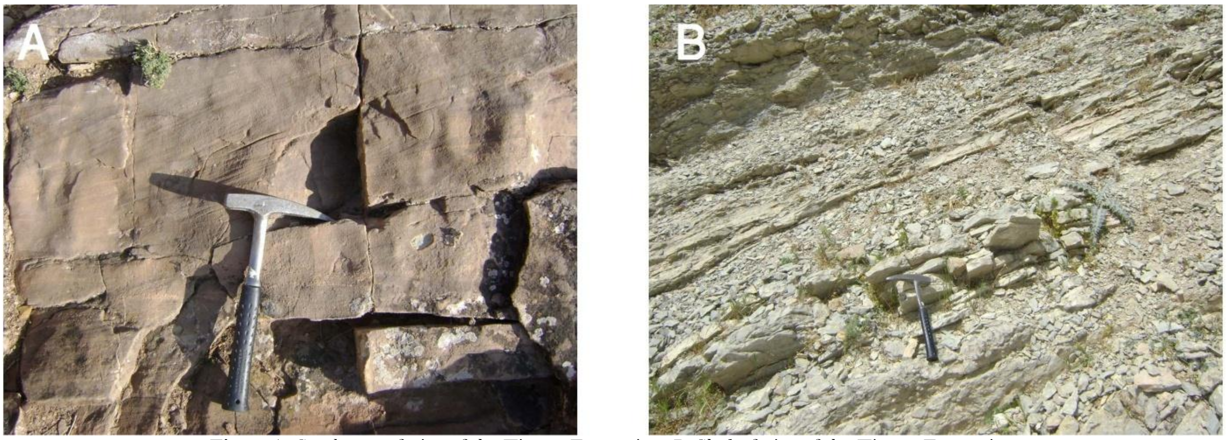

Fig-7. A: Sandstone facies of the Tirgan Formation, B: Shaly facies of the Tirgan Formation

Source: Yavarmanesh (2017)

B) Interpretation and Modeling of Depositional Environments

In the mudstone (A1) and mudstone with fenestral fabric facies (A2), according to the low abundance of fossils and the fine-grained sediments, a low energy supratidal environment is deduced (Nader *et al.*, 2006); (Preto and Hinnov, 2003). Lack of fossils in these facies show a water cycle limit and unsuitable marine organism conditions (Alsharhan and Kendall, 2003); (Warren, 2006). In B1 facies, bioclastic packstone with abundant miliolids and calcareous green algae, orbitolina and other benthic foraminifera in a field of mud show a low energy environment and occur in shallow lagoons with open circulation, generally, miliolid foraminifera is very common in lagoonal environments (Flugel, 2004). Micrite with bioclasts often micritized (B2), common fossils are gastropods, bryozoans and benthic foraminifera that occurs in shallow lagoon with open circulation, bedded limestones with larger foraminifera and mollusks represent the shallow part of the lagoon, in B3 facies, allochems in the micrite such as orbitolina, miliolids, echinoderms, bryozoans, gastropods and few ooids with higher abundance of mud show deposition in a low energy environment. The abundance of skeletal grains such as miliolids and gastropods usually indicate back reef lagoons (Wissler *et al.*, 2003). The composition of the gastropod fauna reflects changes from open marine to more restricted conditions (Einsele, 2000). In B4 facies, an abundance of stenohalina such as brachiopods show that the lagoon was connected to the open sea (Immenhauser *et al.*, 1999). Good sorting of ooid grainstone facies (C2) and high calcite show high energy environment (Tucker, 2001) ooid grainstones occur in high temperature, shallow wavy water (less than 2 m), with a normal salinity (Betzler *et al.*, 2007); (Tucker, 2001). Grain supported ooid grainstones without any mud indicate deposition in a high energy belt (Flugel, 2004); (Hofmann *et al.*, 2004) and in ooid packstone (C1) facies, high mud shows the vicinity of the shoal to the lagoon. Skeletal grains in the D facies group consist of orbitolina, brachiopods, echinoderms and red *algae*, these are sensitive to salinity and an open marine environment is suitable for their life (Flugel, 2004); (Tucker and Wright, 1990); (Sanders and Hofling, 2000). According to the abundance of stenohalina, high abundance of mud and thin bedded layers, we can consider a low energy environment and low sedimentation for this facies which indicates open marine environment (Flugel, 2004); (Martini *et al.*, 2007). Minor amounts of ooids in this facies were moved from adjacent high energy environments. Well-sorted grains and the absence of matrix show formation of mature sandstone which indicates beach-type depositional setting, also absence of skeletal grains indicate a beach setting for this siliciclastic facies (Nicholas, 2000). Green shale that is alternation with mudstone and containing few echinoderms related to open marine environment. Based on the facies description, recent studies (Saffar *et al.*, 2010) and comparison to already presented models (Flugel, 2004); (Read, 1985); (Einsele, 2000) a depositional model of the Tirgan Formationwas constructed for the studied area. Therefore according to the facies types and based on the gradual changes of Tirgan Formation from the Shourijeh siliciclastic Formation to the Sarcheshmeh marine shale Formation and according to distribution SMF types that recognised in the standard facies zones 7 and 8 (FZ7 and FZ8) (Flugel,

2004) (Figs. 8, 9), the environment of this formation is considered as a carbonate ramp-type platform (Bachman and Hirsch, 2006); (Dobrzinski and Bahlburg, 2007) (Fig.10).

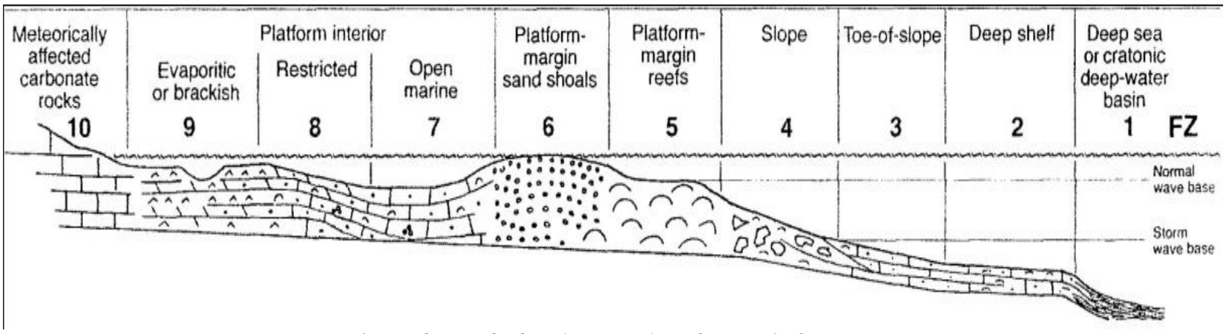

Fig-8. The standard Facies Zones in carbonate platform

Source: Flugel (2004)

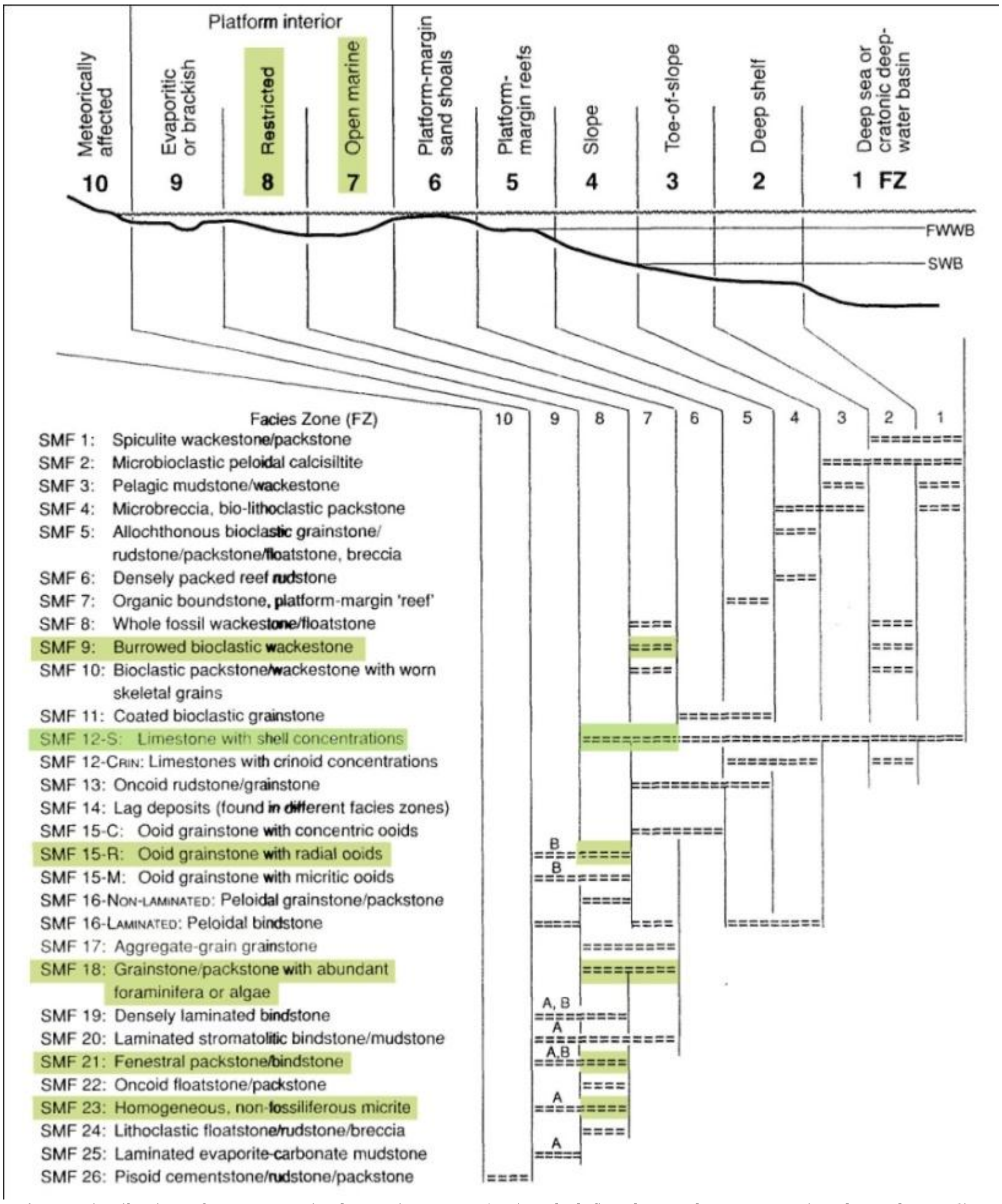

Fig-9. Distribution of SMF types in the Facies Zones (FZ) and define detected SMF types in Ghorogh Syncline
Source: Yavarmanesh (2017)

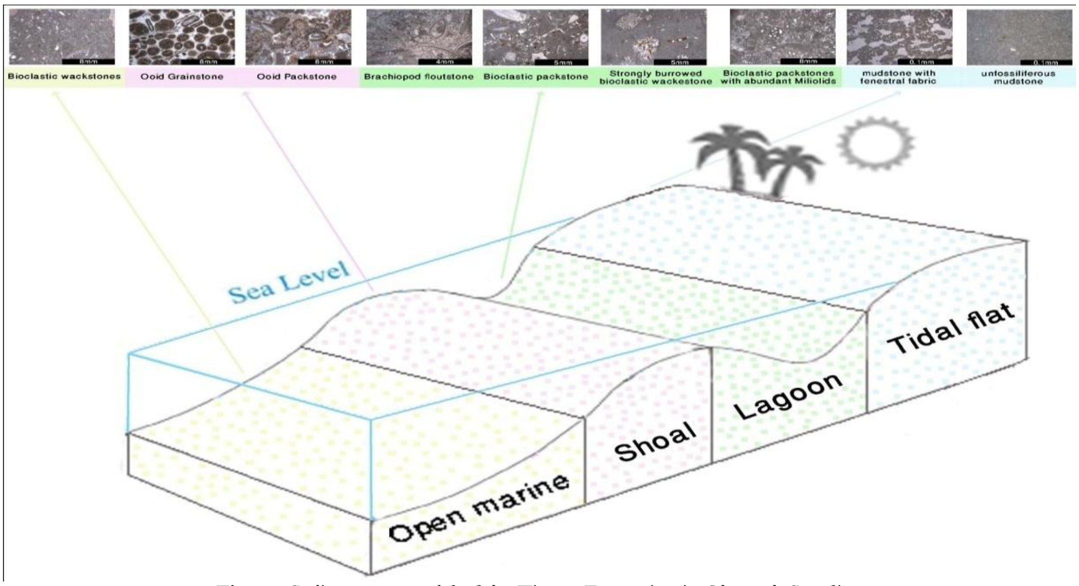

Fig-10. Sedimentary model of the Tirgan Formation in Ghorogh Syncline
Source: Yavarmanesh (2017)

C) Morphotectonic in the Ghorogh Syncline

Morphotectonic studies show in south flank Ghorogh Syncline, oolithic limestones and intercalated shales of Tirgan Formation are slided on the red sandstone of Shurijeh Formation as transitional slides because of lubrication and formed 7 times due to the stresses which are done from the northern syncline to the south of Ghorogh valley and formed the current morphotectonic for the area (Fig. 11, 12). This phenomenon could name as decollement. The transitional slides of Tirgan Formation in Chenaran map (1:100000) wrongly named Shurijeh Formation while in reality these transitional slides are Tirgan Formation and this error repeated in another maps for example Mashhad map (1:250000) (Aryaei *et al.*, 2014) and in past studies the thickniess of Tirgan Formation in south flank Ghorogh Syncline was about 100 m but According to this research the thickniess of Tirgan Formation in south flank Ghorogh Syncline is 251 m.

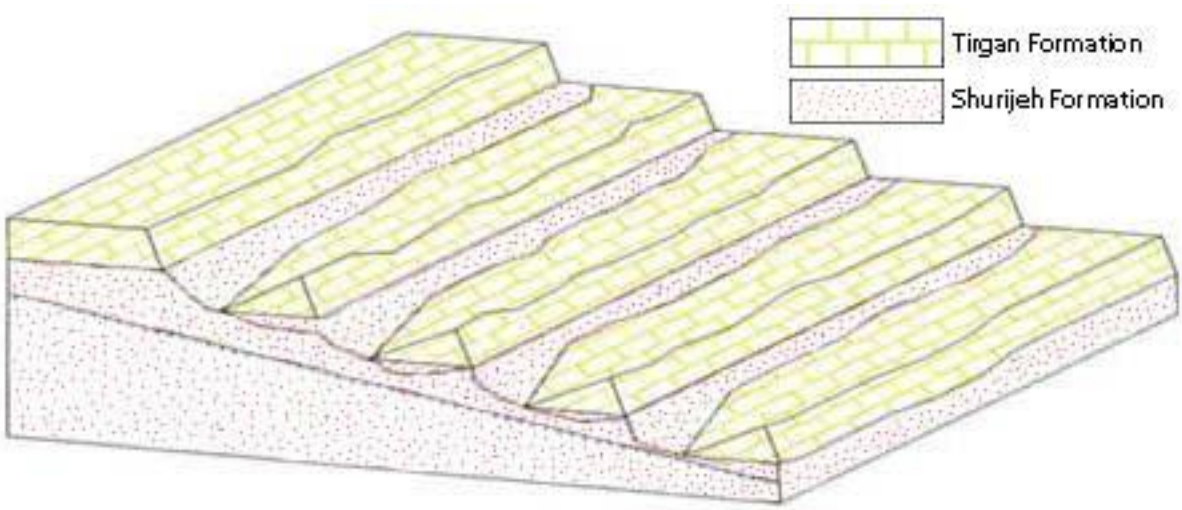

Fig-11. Schematic form of outcrops of the Tirgan Formation on the Shurijeh Formation in Ghorogh Syncline
Source: Yavarmanesh (2017)

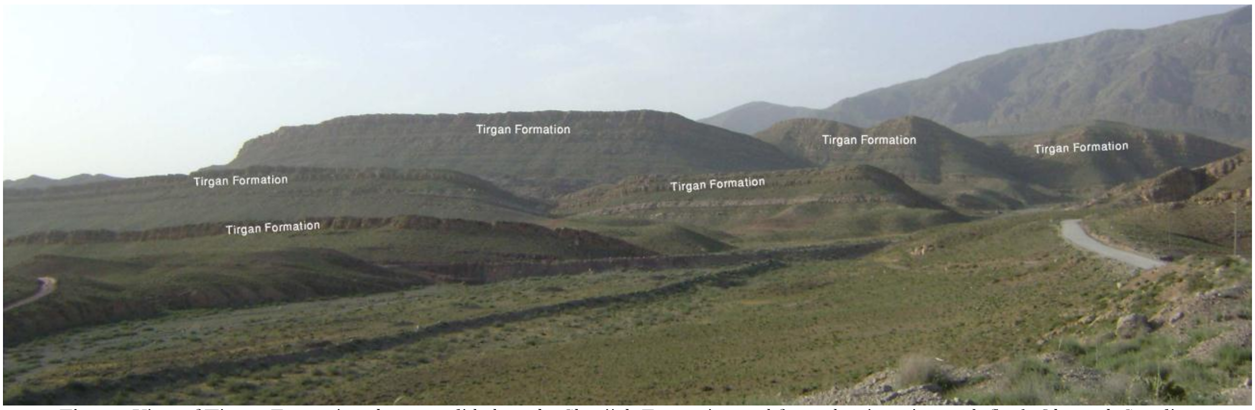

Fig-12. View of Tirgan Formation that was slided on the Shurijeh Formation and formed 7 times in south flank Ghorogh Syncline
Source: Yavarmanesh (2017)

5. CONCLUSION

The early Cretaceous deposits of the Tirgan Formation in the Kopet-Dagh basin (Ghorogh Syncline) are composed of four carbonate facies belts containing 9 carbonate microfacies and 6 microscopic standard facies (SMF). These facies formed in an environment that consisted of tidal flat [unfossiliferous mudstone (SMF 23), mudstone with fenestral fabric (SMF 21)], lagoon [foraminiferal packstones with abundant miliolids (SMF18), strongly burrowed bioclastic wackestone (SMF 9), bioclastic packstone, brachiopod floatstone (SMF 12)], shoal [ooid packstone, ooid grainstone (SMF 15)] and open marine [bioclastic wackestone] deposits, respectively. The microfacies of the Tirgan Formation were deposited in a ramp platform. In the south flank Ghorogh Syncline, stresses which are done from the northern syncline to the south of Ghorogh valley led to the oolithic limestones and intercalated shales of Tirgan Formation are slided on the red sandstone of Shurijeh Formation as transitional slides that these transitional slides of Tirgan Formation in Chenaran map (1:100000) wrongly named Shurijeh Formation while in reality these transitional slides are Tirgan Formation and the really thickness of Tirgan Formation in the south flank Ghorogh Syncline is 251 m.

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Competing Interests: The authors declare that they have no competing interests.
Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

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