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SEDIMENTOLOGY OF THE GOVANDA FORMATION AT GALI BAZA LOCALITY, KURDISTAN REGION, IRAQ

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ABSTRACT

The lithology of the Govanda Formation (Miocene) at Gali Baza locality, northeastern Iraq consists of massive conglomeratic bed at the base, grading upward to thin to medium bedded calcareous sandstone, sandy limestone, calcareous shale, and thin siltstone beds. The petrographic study of clastic and carbonate rocks, based on 21 thin sections, indicates that the major components are different kinds of rock fragments, quartz, altered feldspar and mica for the clastics and non- and/or low-skeletal grains for the carbonates. The study showed that compaction is the most common diagenetic process affecting in the studied samples, appearing in the form of penetration between grains and grain deformation. Accordingly, it is suggested that the deposition of the Govanda Formation, in the studied Gali Baza section, had taken place in a littoral environment with terrigenous clastic supply.

رسوبية تكوين گوڤندا في گلي بازا، إقليم كوردستان، العراق

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المستخلص

تتكون صخارية تكوين گوڤندا (الميوسين) في گلي بازا، شمال العراق من تكتل ضخم من المدملكات في القاعدة تعلوها طبقات من حجر رملي رقيق الى متوسط التطبق، وحجر جيري رملي، وسجيل صخري، وطبقات رقيقة من الحجر الغريني. بينت الدراسه البيتروغرافية للصخور الفتاتيه والكربوناتية، التي تستند إلى فحوصات مجهريه لـ ٢١ شريحه رقيقه إن المكونات الرئيسية في الفتاتيات هي أنواع مختلفة من شظايا الصخور والكوارتز والفلسبار المحورة والمايكا والحبيبات غير الهيكلية وبنسبة أقل من الحبيبات الهيكلية لصخور الكربونات. وكشفت الدراسة أن الضغط هو أحد أهم المسببات للعمليات التحويريه في العينات التي تمت دراستها وتظهر آثاره الأكثر شيوعا على شكل اختراق وتشوه الحبيبات الفتاتيه. بينت هذه الدراسه أن ترسب تكوين گوڤندا في المقطع المدروس في منطقة گلي بازا قد وقع في بيئة قريبه من الساحل مع إمدادات من الفتاتيات القاريه.

INTRODUCTION

The Govanda Formation was first described by Dunnington, Naqib, and Morton (1957, in Bellen *et al*., 1959). The type section of this formation is located on the northwest slopes of the Govanda Plateau, south of Mawat Village and east of Argosh close to the boundary between Iraq and Turkey; at approximately 37°07'58" N, 44°12'53" E, in the Balambo – Tanjero Tectonic Zone.

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Although Govanda Formation has been recognized long time ago, but only a few works have been published about it. This formation was described in more details as an independent stratigraphic unit by Buday (1980). The Chama Formation and Lailuk Formation recognized respectively by Morton, 1951, and documented by Dunnington, 1956 and Bolton, 1958; in Bellen *et al*., 1959, near Chama and Lailuk villages in Mergasur District, were included in Govanda Formation by Bellen *et al*. (1959). Al-Hashimi and Amer (1985), based on petrographic study, described and reported some microfacies found in the Govanda Formation by defining fossil content and explaining depositional environment. The locality, geologic, and lithologic sequence of the Govanda Formation were displayed on the Geological Map of Iraq (Sissakian, 2000). The earlier descriptions were confirmed by Jassim *et al*. (2006) who drew tectonic and isopach maps of the (Early – Middle Miocene). More detailed sedimentological and stratigraphic study was performed by Smail (2015).

The studied sequence is located in Erbil Governorate, north and northwest of Soran District, near the southern border of the Thrust Zone (Zagros Suture). The study area is restricted to Gali Baza – Badlian Village at 36°43'33.7" N and 44°32'12.9" E (Fig.1). The aim of this study is to determine the sedimentological characteristics of the Govanda Formation in the locality of Gali Baza, Kurdistan Region by describing the petrography of the formation in detail; determining diagenetic processes and lithofacies types and defining the lower and upper contacts in order to establish the depositional environment and reconstruct paleogeographic model of the basin.

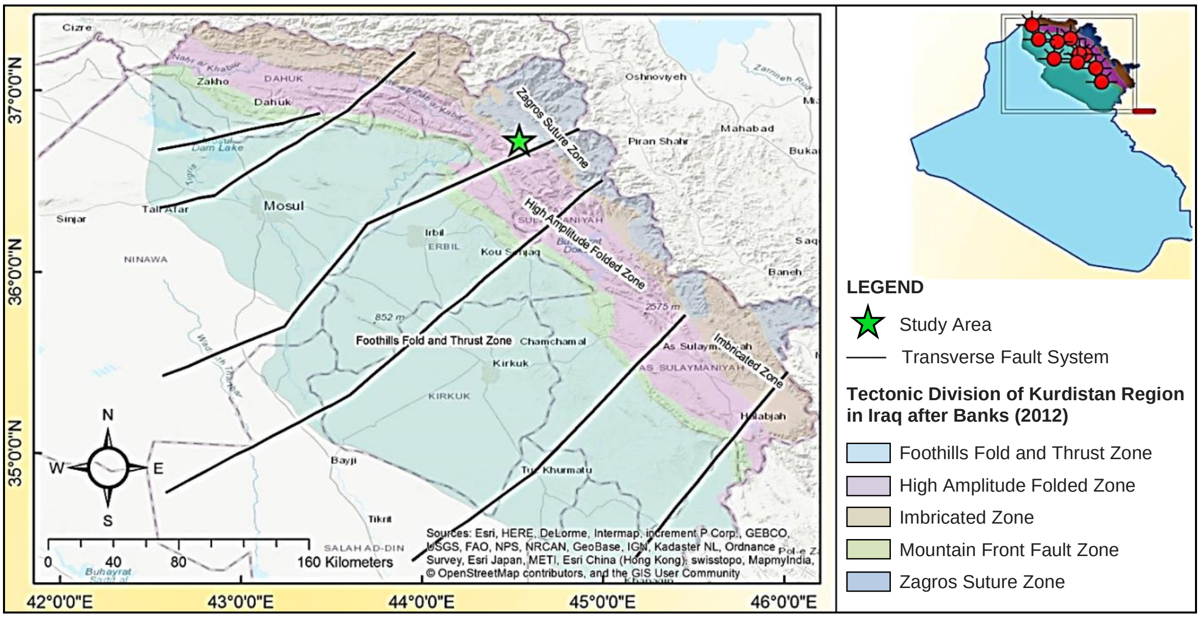

Fig.1: Location of the studied outcrop

METHODOLOGY

The field work was carried out in Gali Baza area, Soran District, where Govanda Formation is well exposed. The thickness, lithology, color, sedimentary structures, textures, and fossil content were documented in a selected section. After removing the weathered parts, 35 fresh rock samples were carefully collected. A total of 21 thin sections were prepared and petrographic description was handled by polarizing microscope in the petrographic laboratory at the Department of Geology, Salahadin University, Erbil.

GEOLOGICAL SETTING

The palaeogeographic evolution during the Early and Middle Miocene is marked by the development of a wide, but relatively shallow basin (Jassim and Buday, 2006). By the end of the Aquitanian and starting of Burdigalian, subsidence in the slowly sinking normal marine basin, extending from northwestern Iraq to southeastern Iran, became more rapid in some areas and ceased in others, resulting in the formation of a series of small elongated basins such as that of the Govanda basin and other equivalents (Jassim *et al*., 2006).

Geologically, the Govanda Formation occurs within the strike of Bradost anticline and Spi Balies – Mama Ruta structure at the top of Tanjero Formation (Smail, 2015). There is an angular unconformity between the lower part of Govanda Formation and the underlying Tanjero Formation. The lower contact is very clear, in most areas composed of distinct erosional surface of Tanjero Formation. The upper boundary is gradational and conformable with Merga Red Beds (Fig.2) (Bolton, 1958; in Bellen *et al*., 1959; Buday, 1980).

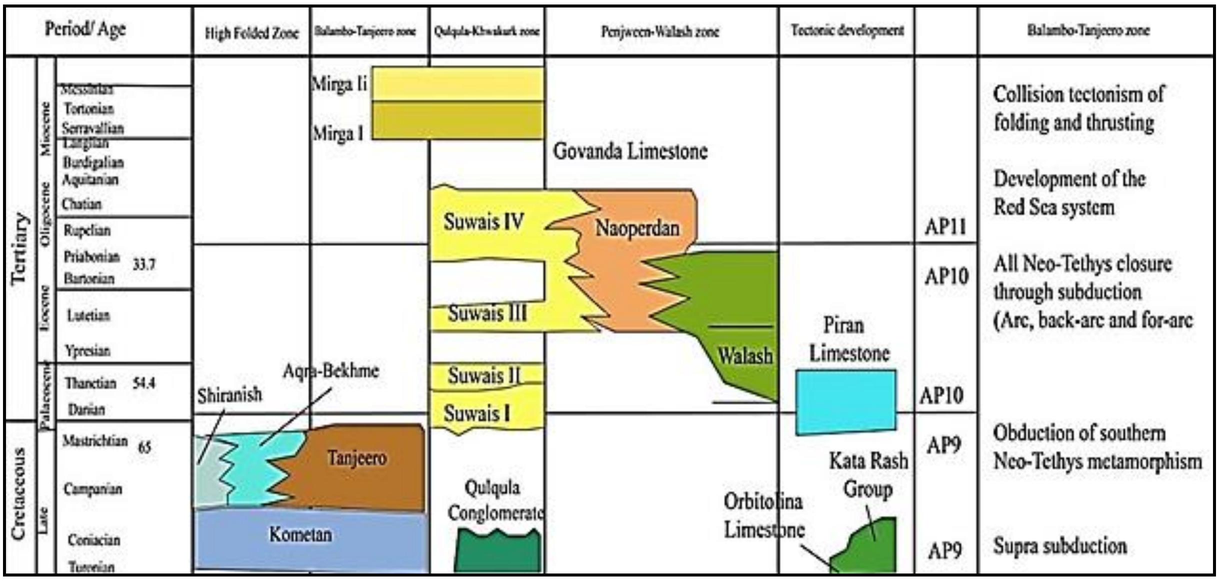

Fig.2: Tectonostratigraphy of the Zagros Suture Zone (after Jassim *et al*., 2006)

The exposures of the formation in outcrops has patchy distribution, extending over a long strip, adjacent to the Zagros Thrust Zone, and widely distributed in the Imbricate Zone covering wide areas in Govand, Qalandar and Rusty Valley with some patches in Qandil, Penjwin, Hawraman, and Halabja localities. The thickness of the formation varies from place to place, at the type locality, it is about 120 – 150 m according to Bellen *et al*. (1959) and in the Gali Baza section the thickness of formation is about 106 m (Fig.3), but towards the southeast the thickness is reduced. In Rawanduz area, the formation occurs in mostly disconnected and in the Ranya area the thickness amounts to few tens of meters only, or is sometimes even below 10 m. More towards the southeast the thickness increases again (Buday, 1980).

According to Buday (1980), the formation might be correlated with the Jeribe Formation in Iraq, and has well expressed correlative in Turkey and Iran, where the middle limestones of the Beygur Series are surely correlated with Govanda (Altinli, 1966). Towards the southeast, in Iran the Guri Limestone Member of the Mishan Formation and upper Asmari Formation are very close to Govanda Formation (James and Wynd, 1965).

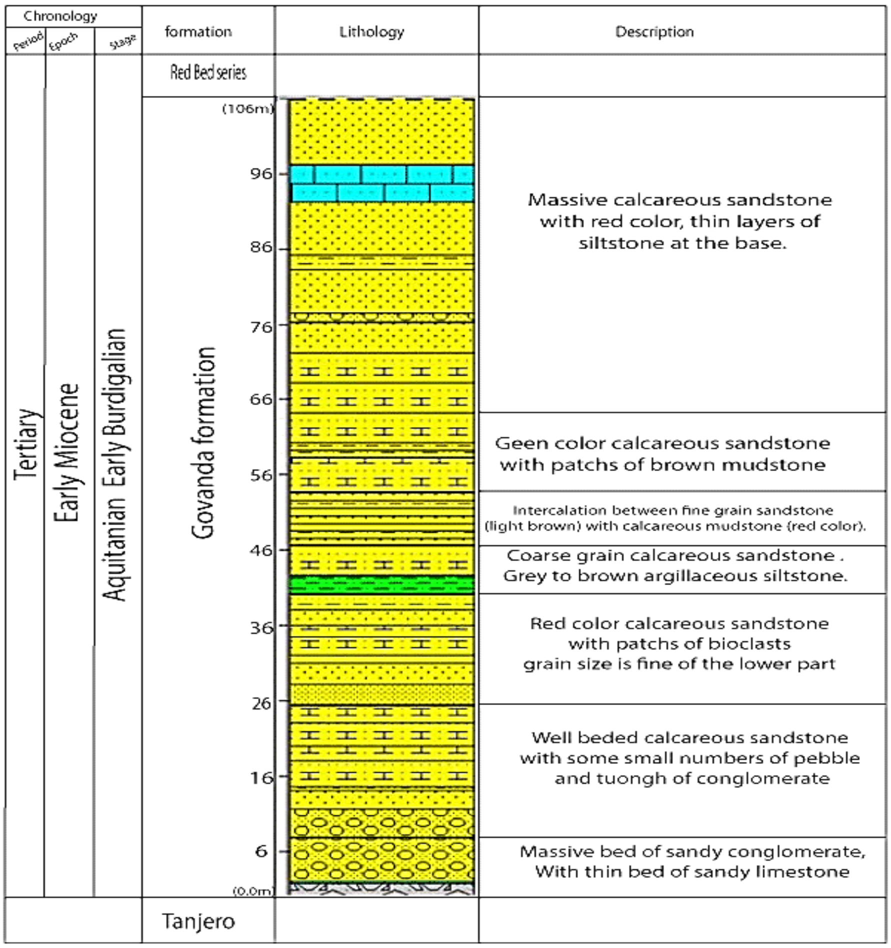

Fig.3: Stratigraphic column of the Govanda Formation in the Gali Baza section, Soran District, Kurdistan Region, Iraq

PETROGRAPHY

The petrography of the Govanda Formation in the studied section show that the main components are composed of clastic and carbonate sedimentary rocks. The clastic part is classified based on Folk (1974) and the carbonate classification is based on Dunham (1962).

- **Clastics**

This part is mainly composed of sandstone with quartz, feldspar and rock fragment as the framework constituents. The formation is dominated by sandstone in most parts of the Gali Baza section and characterized by low content of quartz grains.

– **Rock Fragment:** The studied sandstones (Fig.4) contain detrital rock fragments composed mainly of silt-size lithic fragments, quartz, feldspar, and clay minerals. The rock fragments in the Govanda Formation consist of:

- **Sedimentary rock fragments (SRF):** Fragments of older sedimentary rocks are common in the basal conglomerates. Many sandstone samples contain reworked fragments of siltstone, shale, limestone, or fine sandstone. Generally these fragments are not resistant to abrasion, so they indicate brief transport if they are present in important amount (Folk, 1974).

- **Igneous rock fragments (IRF):** The igneous fragments of altered volcanic rocks and the presence of biotite, muscovite, and feldspar envelopes around the grains are especially characteristic of granites and granitic pegmatites (Figs.4A and 4B).
- **Metamorphic rock fragments (MRF):** Metamorphic rock fragments consist of sand or gravel-size pieces of quartz and mica (Fig.4C). The presence of slate and quartzite grains (Fig.4C) indicates the presence of metamorphic rocks in the source area. However, under intense weathering, the MRF disaggregate into their components, quartz silt and fine mica and then disappear from sand fraction (Folk, 1974).

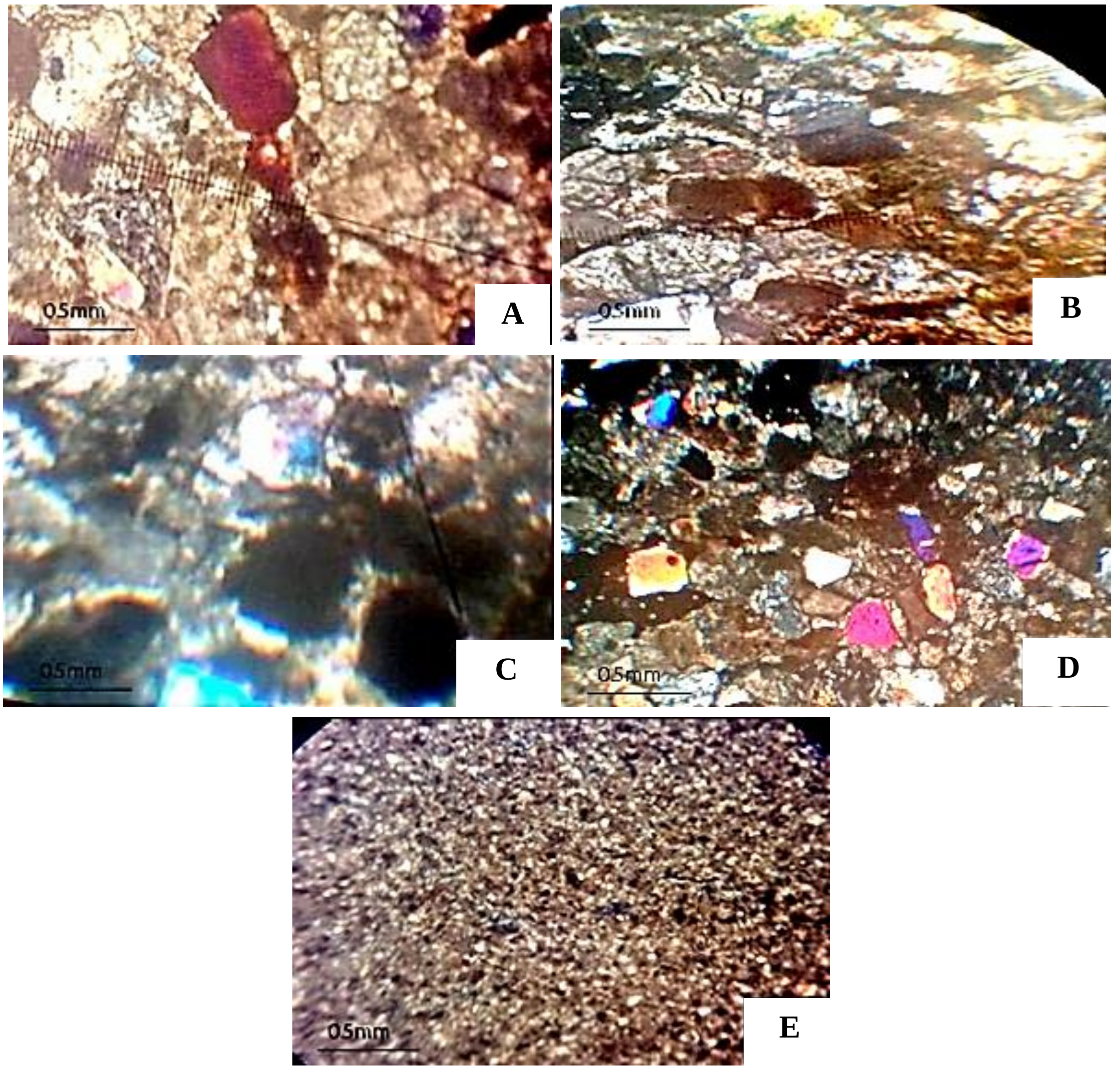

Fig.4: **A)** Fragments of granites and granitic pegmatites (Mag.: 40X, XPL); **B)** Altered feldspars (Mag.: 40X, XPL); **C)** Metamorphic rock fragment, slate and quartzite (Mag.: 40X, XPL); **D)** Monocrystalline quartz grains, well sorted, subangular to subrounded, fine to medium grained (Mag.: 30X, XPL); **E)** Siltstone; groundmass is composed of clay material containing fine grains of quartz, altered mica and feldspar (Mag.: 30X, XPL)

– **Quartz:** Quartz grains are dominantly monocrystalline (Fig. 4D), well sorted, sub angular to subrounded, fine to medium in grain size, with straight extinction.

– **Feldspar:** The feldspars are dominated by orthoclase (Figs.4B and 4E).

Based on Folk's (1974) classification for sandstone (Fig.5), the sandstone in the studied samples of the Govanda Formation is mainly a litharenites, which are sandstones with a >5% lithic fragments, though quartz and feldspar are usually present as well, along with some clayey matrix.

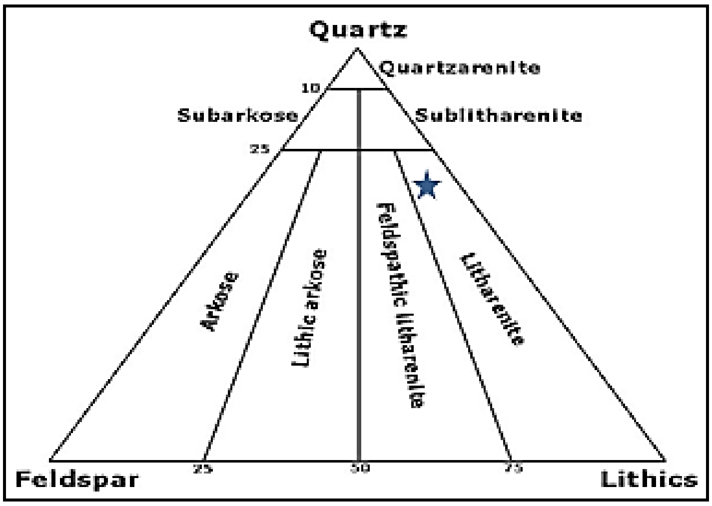

Fig.5: The studied sandstones (blue star) in the litharenite field according to Folk (1974)

- **Carbonates**

Dunham's (1962) classification of carbonate rocks is based mostly on detailed study of microfacies where grain types and depositional textures are considered. Dunham's (1962) classification divides facies into groundmass (micrite and cement) and carbonate particles (grains). Tucker (1981) divides the grains into skeletal grains that include fossils and their clasts, and non-skeletal grains. According to Flügel (1982), the groundmass describes the primary matrix, broadly defined as micrite and sparite formed by cementation and neomorphism. The matrix is the part that links all grains and stands as indicator of power of water current and types of depositional environment (Folk, 1959).

– **Cement**

- **Sparite:** The presence of spary calcite in intergranular pore spaces in grainstone of shoal between pellets at the middle part of Gali Baza section indicates that the grain framework voids were empty of lime mud at the time of deposition, suggesting under agitated water conditions (Flügel, 1982). In Govanda Formation, various types of cement are found in various percentages, mainly granular, drusy and blocky (Fig.6A). The sparite is the crystalline carbonate material associated in general with shallow marine shoal environments.

– **Matrix**

- **Micrite:** Most of micrite in the studied samples of Govanda Formation was produced by biochemical precipitation, through algal photosynthesis. Bacterial activity and decaying organic matter are other possible sources of micrite (Fig.6B).

– **Grains**

- **Skeletal grains and biocalsts:** The skeletal grains are represented mainly by the preserved hard parts of the fossil assemblages with their fragmented bioclasts (Fig. 6C). Fossils (include miliolids) are the main skeletal grains in the studied samples of Govanda Formation.

- **Non-skeletal grains:** Non-skeletal grains in the studied carbonate rocks of Govanda Formation include: intraclasts and pellets (Figs.6C and 6D).

– **Microfacies analysis:** Microfacies are used for the interpretation of depositional environments of Govanda Formation in the studied locality. The type, size, shape, and distribution of skeletal grains are considered good indicators of depositional environment (Flügel, 2010). In the studied section the following main microfacies are identified in the Govanda Formation:

- **Mudstone/ Wackstone Microfacies:** This microfacies contains 8 – 30 % grains (pllets and miliolids) that occur at the upper part of the formation in lagoonal reef environment indicating quiet water deposition (Fig. 6B).

- **Grainstone Microfacies:** This microfacies contains 50 – 60 % grains. The grains are pellets and intraclast (Fig.6A). This microfacies occurs at the middle part of Govanda Formation representing a shoal environment.

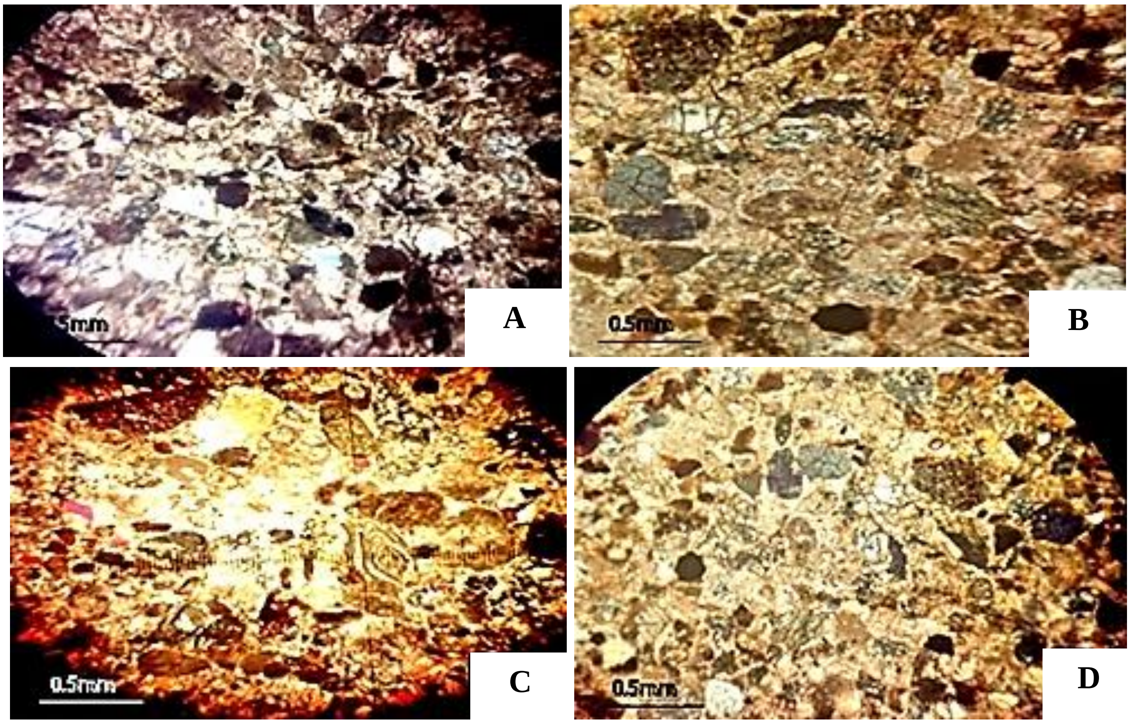

Fig.6: **A)** Sparry calcite cement in intergranular pore spaces of a shoal grainstone composed of skeletal grains and pellets at the middle part of Gali Baza section (Mag.: 30X, XPL); **B)** Mudstone-wackstone microfacies, mostly found at the upper part of the formation (Mag.: 40X, XPL); **C)** Sandy limestone with skeletal grains of miliolids and other fossils and non-skeletal grains like intraclasts. The groundmass is composed of micrite (Mag.: 30X, XPL); and **D)** Non-skeletal grains of pellets and intraclasts in micrite groundmass (Mag: 30X, XPL)

DIAGENESIS

Diagenetic history and evolution of the Govanda Formation in the studied section have been affected by a series of processes including: physical and chemical compaction; pressure solution; cementation; micritization and development of micritic envelopes; neomorphism; silicification; dissolution; and fracturing that affected and changed the original texture (Tables 1 and 2). The main diagenetic processes observed in the Govanda Formation in this locality are:

- **Compaction**

– **Chemical compaction:** The most obvious effect of pressure solution is represented by the development of stylolites and solution seams (Fig.7A and 7B).

– **Mechanical compaction:** Various effects of mechanical diagenesis are found in the studied samples from the sediments of the Govanda Formation (Fig.7C).

Table 1: Stages of diagenetic processes in the studied sequence

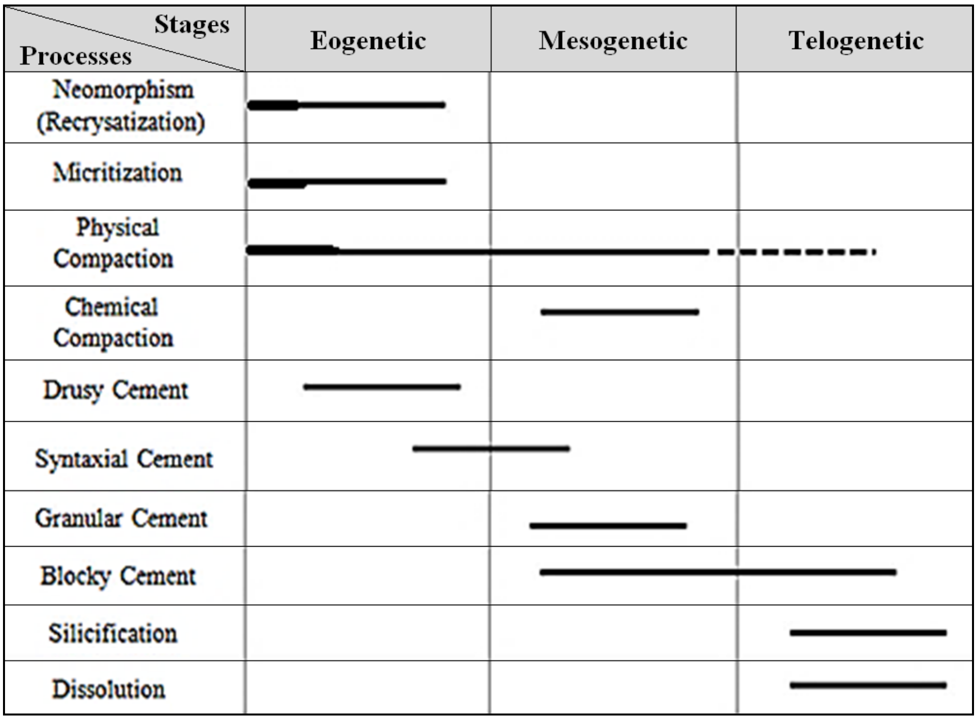

Table 2: Classification of diagenetic processes in the Govanda Formation (according to Englehard, 1977)

Diagenesis			Presence in Govanda Formation
Division		**Processes**	
1- Mechanical diagenesis		- Compaction	C
2- Chemical diagenesis	a- Isochemical	- Neomorphism	C
		- Solution	P
		- Cementation	C
	b- Allochemical	- Dolomitization	R
		- Dedolomitization	R
		- Silicification	C
		- Phosphatization	R

C: Common; P: Presence; and R: Rare

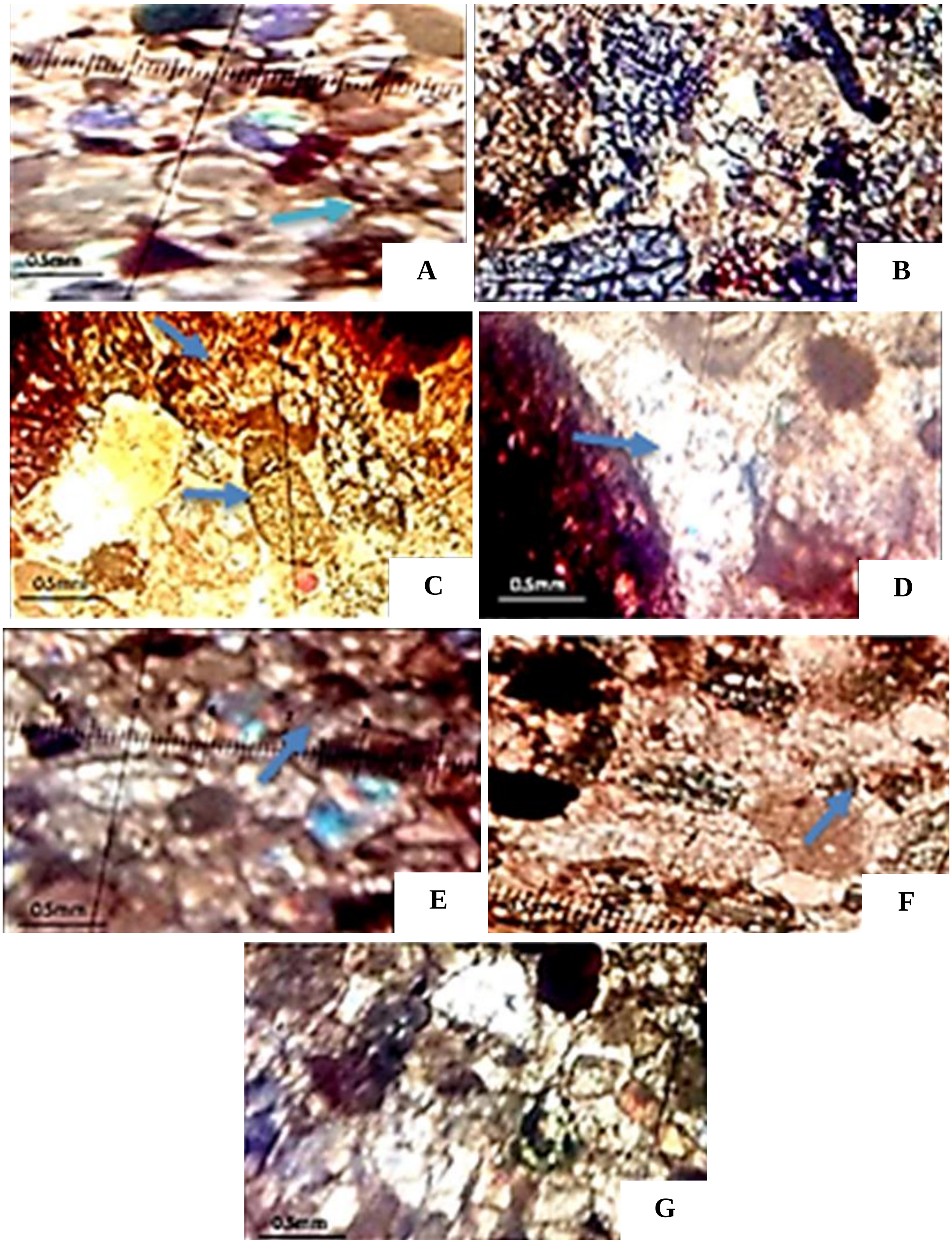

Fig.7: **A)** Pressure solution represented by the development of penetration between grains and solution seams (Mag.: 40X, XPL); **B)** Dissolution of a fossil after cementation (Mag.: 40X, XPL); **C)** Mechanical compaction (Mag.: 40X, XPL); **D)** Drusy and intergranular cement within the grains. (Mag.: 40X, XPL); **E)** Silicification (chertification) of skeletal grains (shells) (Mag.: 40X, XPL) **F)** Micritization of skeletal grains (shells) (Mag.: 40X, XPL) and **G)** Recrystallization of bioclasts and other grains (Mag.: 40X, XPL);

- **Cementation**

The common cement types observed in the studied samples are:

– **Granular cement:** Granular cement is a more common type of cement observed infilling several types of skeletal grains (Fig.7D), compaction-related fractures and veins.

– **Drusy cement:** In many cases, drusy cement is used as a synonym for granular cement, but the main differences are, as cited by Flügel (1982), the planar crystal boundaries of drusy cement, and its wider range of grain sizes (Fig.7D). This type of cement is observed at the lower part of the studied section of Govanda Formation.

– **Blocky cement:** This type of cement is found in fractures and cracks, confirming its late diagenetic occurrence and its formation in deep burial conditions under the influence of meteoric waters (Flügel, 1982).

- **Silicification**

The petrographic study of limestone shows that there is a selective silicification (chertification) which affects shells of skeletal grains, and some other grains (Fig.7E).

- **Micritization**

The present study, in all parts of the section, shows that micritization has preferentially exaggerated thin shells of most skeletal grains (Fig.7F).

- **Recrystallization**

Recrystallization of bioclasts and other carbonate grains is common in the studied samples (Fig.7G).

DISCUSSION

The overall, evolution of the sedimentary basins, in the Miocene in this area was controlled by tensional or collision tectonics which led to the formation of shallow intermountain basins, accompanied by the positive uplifting of the adjacent area (Jassim *et al*., 2006). The Govanda Formation represents a shallow marine reefal environment where neritic, back-reef, reef, and fore-reef units were deposited in a narrow carbonate-rimmed inner shelf, of moderate to low energy environment, occasionally connected with open marine, with considerable terrigenous supply that dominated the shelf facies (Buday, 1980). The deposition of the Govanda Formation is suggested to have taken place in an elongated narrow basin, extending from northeast towards southwest, between the Suture Zone and Bradost paleo-high (Jassim *et al*., 2006).

The Govanda Formation in the Gali Baza section is composed of polygenic intraformational conglomerate at the base, with different thicknesses from section to another, overlain by different types of limestone, sandy limestone and highly fossiliferous limestone which are occasionally intercalated with some thin beds of red argillaceous and calcareous shale. In the studied section the formation is characterized by the overwhelming presence of terrigenous material, composed of massive conglomerate bed at the base, overlain by thin to medium bedded calcareous sandstone, sandy limestone, calcareous shale, siltstone, thin siltstone beds, silty mudstone, and sandy marl alternating with pebbly sand (Fig.3).

The lithology of the formation is strongly affected by terrigenous supply from the nearby rising land, as testified by the presence of terrigenous clastics, not only at the bottom, but sometimes intercalating with the overlying limestone as well. The clastic materials are mostly composed of rock fragment of metamorphic and igneous origin, transported to the basin from the adjacent rising area. The presence of igneous and metamorphic rock fragments indicates that the clastic materials did not suffer long distance transportation. The conglomerates and coarse clastics were probably brought to the basin of the Govanda Formation at Gali Baza locality via the generation of paleo-channels developed during the Miocene and transported terrigenous material from the nearby mountain belt to the basin. The Carbonate part is composed of two microfacies: mudstone/ wackstone and grainstone. These two microfacies, based on Flügel (2010), belong to restricted and shoal in shelf environment, respectively.

Based on field observations and tectonic history of the area during the Miocene, besides the type of sandstone and structural features of the area, the formation was deposited in a littoral environment with continuous terrigenous supply from nearby sources. The narrow and shallow intermountain reefal system was influenced by frequent clastic supply from the neighboring rising ridge area of the Zagros Mountains, controlled by the configuration of the basin and drainage system (Fig.8) and manifested by the succession of sandy terrigenous beds in the sequence. The trend of reef development was patchy and repeated several times. The discontinuity of reefal buildups was most probably influenced by bathymetry related to the configuration of the basin floor and controlled by tectonic activity. Based on microfacies analysis of the carbonate rocks, the Govanda Formation grades up ward from agitated shoal environment in the middle part (Grainstone Microfacies) to lagoonal-reefal quiet environment (Mudstone/ Wackstone Microfacies) in the upper part.

The sedimentary succession of the Govanda Formation, as found in the present study, has suffered various types of diagenetic modifications induced by mechanical and chemical factors. The early diagenetic modifications included recrystallization, micritization and physical compaction, whereas dissolution and silicification are common as late diagenetic features.

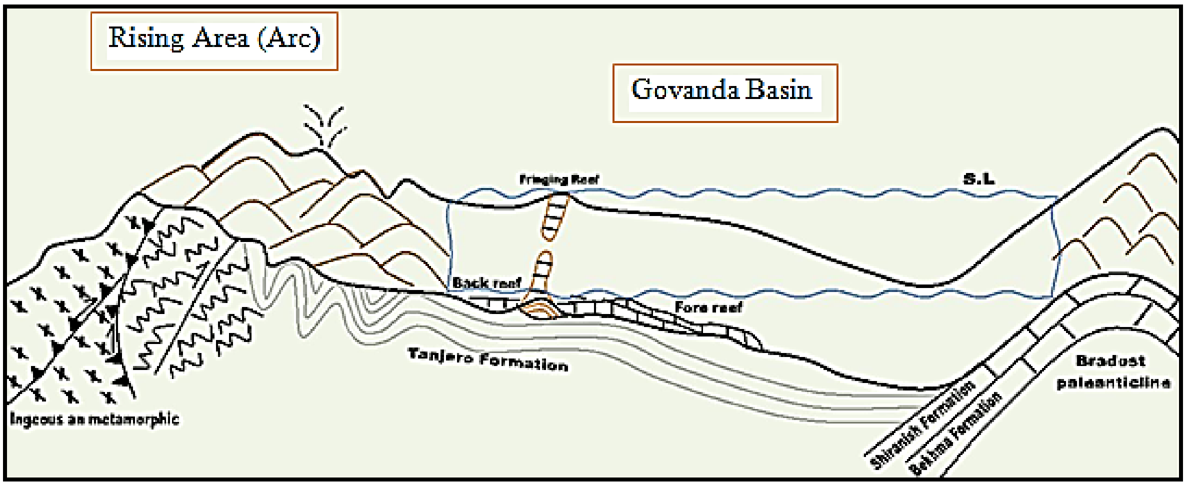

Fig.8: Depositional model of Govanda Formation during
Early Miocene (Smail, 2015)

CONCLUSIONS

- The Govanda Formation in the studied locality consists mainly of carbonate and clastic rocks. It is strongly affected by the terrigenous supply from the nearby rising land, as testified by the presence of metamorphic and igneous rock fragments within various beds and horizons intercalated with calcareous limestone.

- The fine-clastic strata, such as calcareous shale and siltstone, record the transition from channel deposits at the base to littoral environments upward, with features such as sandy marl alternating with pebbly sand. Therefore, the depositional environment of the Govanda Formation in the Gali Baza section represents a littoral environment with active clastic supply. Microfacies analysis indicates transition towards a quieter lagoonal/ reefal environment upward in the sequence.
- Compaction is the most common diagenetic process, manifested in the form of penetration between grains and grain deformation. Neomorphism, cementation and silicififation are other common diagenetic modifications.

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