# MICROFACIES AND DEPOSITIONAL SETTING OF THE EARLY EOCENE CHOR GALI FORMATION, CENTRAL SALT RANGE, PAKISTAN

S. Ghazi, A. Ali, T. Hanif, S. Sharif. Z. Sajid and T. Aziz

Institute of Geology, Punjab University, Quaid-e-Azam Campus, Lahore-54590, Pakistan.
Corresponding Author E-mail: ghazigeo6@gmail.com

**ABSTRACT:** The Early Eocene succession is well exposed in the Central Salt Range; Pakistan consisted of the Nammal Formation, the Sakesar Limestone and the Chor Gali Formation. The present work is focused on detailed microfacies and depositional setting of the Chor Gali Formation in the Salt Range. Four stratigraphically important sections Khajula, Tatral, Badshah-Pur and Karuli were measured. Twenty five samples were collected and analyzed from these sections to illustrate the temporal as well as spatial variations in facies. The thickness of the formation varied from 20 to 30 meters. Formation has predominantly composed of thin to well bedded limestone, shale and marl. The limestone units are argillaceous, marly and rich in larger foraminifers while the shale was highly fossiliferous and variegated in colour. Six dominant litho-units have been established based on the field observations. The microfacies analysis allowed identifying and describing diagnostic microfacies including bioclastic mudstone, bioclastic wackestone, bioclastic packstone and bioclastic grainstone. The study of benthic larger foraminifera revealed ten age diagnostic species; *Nummulites mamillatus* (Fichtel and Moll), *N. atacicus* Leymerie, *Assilina spinosa* Davies and Pinfold, *A. subspinosa* Davies and Pinfold, *A. laminosa* Gill, *A. granulosa* (d'Archiac), *A. placentula* (Deshayes), *Lockhartia tipperi* (Davies) and *L. conditi* (Nuttall). Field observations and microfacies analysis suggested that the deposition of formation took place in inner shelf conditions. Presence of shallow water benthic larger foraminifera also support inner shelf environment for the Early Eocene Chor Gali Formation.

**Key words:** Early Eocene, Chor Gali Formation, Microfacies, Larger benthic foraminifera, depositional setting, Central Salt Range.

## INTRODUCTION

The Salt Range of Pakistan is located to the south of the Potwar Basin and east of the Jhelum River where it forms a southwardly-convex outcrop belt with a general east-west trend (Fig. 1). The Salt Range has a series of pronounced salt anticlines at its core that has resulted from non-compressional diapirism which is superimposed on earlier compressional structures. Plastic flow of mobile evaporites has caused the uneven development of fold structures, whereby anticlines tend to exhibit sharp crests, whereas synclines have flat bases (Ghazi and Mountney, 2009, 2011). Drainage patterns have exploited the axes of the anticlines and several steep-sided gorges being developed, including the spectacular Khewra, Nilawahan, Warchha and Nammal Gorges, which exposed Cambrian to Neogene strata, (Fig. 2) including the Eocene Chor Gali Formation discussed in this study.

Early Eocene (Ypresian) is well developed through out the Salt Range. During Early Eocene time open marine platform conditions prevailed depositing three important stratigraphic units in the Salt Range, which consisted of the Nammal Formation, the Sakesar Limestone and the Chor Gali Formation. The present work is focused on detailed microfacies analysis of the Chor Gali Formation in the Salt Range. Four stratigraphically important sections Khajula, Tatral, Badshah-Pur and Karuli were measured (Fig. 1).

The term "Chor Gali Beds" (Pascoe ,1920) formalized as Chor Gali Formation after the Chor Gali Pass in Khair-e-Murat Range (lat. 33°26' 30"N; long. 70°41'E). The Chor Gali Formation consists of thin-bedded grey, partly dolomitized and argillaceous limestone with bituminous odour from freshly broken surface (Ali, 2012; Shah, 2009). The upper part of the formation is composed of shale of greenish-yellow color, which is soft and calcareous with well-beded limestone of yellowish and greenish grey color (Abbas, 1989). The Chor Gali Formation conformably rests on the Sakesar Limestone (Early Eocene) and is unconformably overlained by the Kamlial Formation (Miocene) in the Central Salt Range (Ali, 2012).

The objective of this study was to present detailed microfacies of the Chor Gali Formation along with variety of biota and to record possible depositional setting of the Chor Gali Formation in the Central Salt Range.

## METHODOLOGY

The study area comprised of four stratigraphic

sections including Khajula, Tatral, Badshah Pur and Karuli. These stratigraphic sections were carefully sampled. The samples were mainly collected from limestone units and thus 80 thin sections were prepared from all sections for detailed microfacies and micropalaeontological studies. Microfacies were identified based on the classification proposed by (Dunham, 1962).

## RESULTS AND DISCUSSION

**Lithostratigraphic units**: Six main lithological units were recorded on the basis of detailed outcrop studies (Fig. 3).

(a)Greenish grey shale (Unit-A); This shale unit was recorded as the basal part of the Chor Gali Formation with maximum thickness of about 0.5 m in the Karuli area (Fig. 4A). It was greenish-grey, light-grey coloured on fresh surface and weathers to dark-brown and reddish colour. This shale formed wavy contact with the Sakesar Limestone, and contained abundant larger foraminifera.

(b) Alternate limestone and shale (Unit-B); this part of the formation consisted of 5 m to 8 m thick alternate thin-bedded limestone and shale (Fig. 4B). The limestone was light yellow, off white and tan in colour and weathers to grey. It was highly fossiliferous and marly at places. It showed concoidal fractures and rare calcite veins were also observed. Shale was greenish grey and fossiliferous.

(c) Variegated shale (Unit-C); this part of the formation comprised of shales of variegated colour which included reddish-brown, light-grey and yellowish-green (Fig. 4C). Average thickness of this unit was about 3 m.

(d) Laminated limestone interbedded with shale (Unit-D); Limestone of this unit was of light grey, brownish grey, off white and light green coloured in the lower parts (Fig. 4D). Thickness of this unit varied from 3.5 m to 5.5 m. Limestone was thinly laminated and was highly fossiliferous in the middle parts. While limestone was generally, light-grey colour, argillaceous and fossiliferous in the upper parts. The shale of this unit was yellowish brown, splintery and fossiliferous.

(e) Thin-bedded Limestone (Unit-E); this unit was about 5.5 m thick, composed of three types of limestone. The basal parts were thin-bedded limestone of light grey colour and weathers to yellow. Middle parts were thin-bedded limestone which differed from the basal part due to the presence of larger foraminifera. Upper part was composed of tan- to light-pink coloured medium bedded limestone. This limestone was very fine-grained, compact and crystalline. Concoidal fracture and calcite veins were also observed.

(f) Argillaceous limestone (Unit-F); This unit was composed of argillaceous limestone of light-grey to off-white colour and weathers to dark-grey and light-yellow. Thickness of this unit was 1.5 m and outcrop of this unit was highly fractured due to the tectonic activity.

(g) Intrabasinal conglomerate (Unit-G); On the top of the formation 1.5 m, clast supported intrabasional conglomerates were recorded. Rounded to well-rounded were mainly derived from carbonate rocks. The size of clasts varied from 0.4 to 0.8 m in diameter and contained fossils and chert.

**Microfacies analysis:** Nine microfacies were identified from bottom to top on the basis of petrographic studies of the Chor Gali Formation.

***Bioclastic Mudstone* (Chor Gali1):** This facies represented micritic limestone, comprising of about 5% bioclasts in micritic matrix consisting of 90-95% of these facies. The bioclasts were the fragments of planktonic forams. Calcite filled veins were very common in thin sections. Mudstone was replaced by spar that could be seen in the form of patches (Fig. 5A).

***Bioclastic wackestone*:** These facies represented limestone which was composed of about 25-30% bioclasts. The prominent bioclast was genus *Nummulites*, ranging in size from 2-5mm, however, few grains <2mm were also present (Fig. 5B).

***Bioclastic mudstone*:** These facies represented a fine-grained limestone which was composed of dominantly of carbonate mud and it appeared to be primary depositional fabric. Broken shells were about 5% (Fig. 5C).

***Bioclastic packstone*:** These facies were composed of 40% bioclasts fossiliferous limestone. The prominent forminiferal genera bioclasts were *Nummulites* and *Assilina*. Spar cement showed a patchy behaviour with no definite crystal shape and hence could be a product of compaction due to dia ogenesis (Fig. 5D).

***Bioclastic mudstone*:** These facies were composed of micrite of about 90 - 95%. Irregular and high amplitudes shaped stylolites were common (Fig. 5E).

***Bioclastic mudstone to wackestone*:** These facies were composed of 15-20% of bioclasts. The prominent bioclasts were the forminiferal of genera *Assilina*. Bioclasts were internally micritized and replaced by spar at places (Fig. 5F).

***Bioclastic mudstone*:** these facies were dominantly composed of micrite. At few places, micrite were replaced by spar (Fig. 5G).

***Stylobedded bioclastic mudstone*:** These facies were mainly composed of micrite. Very low amplitude stylolites were found, they were arranged in parallel sets showing stylobedded pressure solution structures (Flugel, 2010), Fig. 5H.

***Bioclastic grainstone*:** These facies were composed of 95% of bioclasts. The prominent bioclasts were the forminiferal genera *Nummulites* and *Assilina*. Calcite was present as intergranular cement. Stylolites were also

present indicating compaction (Fig. 5I).

**Faunal assemblage:** The Chor Gali Formation in the study area was geologically investigated for micropalaeontological studies. In comparison to other organisms like algae and gastropods the amount and distribution of larger benthic foraminiferal species in the study area were vast. These species were quite common in the equivalent geological deposits of other parts of the world. The study of the Chor Gali Formation in the Central Salt Range yielded nine age diagnostic benthic larger foraminiferal species (Figs. 7, 8). These larger benthic foraminiferal species included; *N. mamillatus* (Fichtel and Moll), *N. atacicus* Leymerie, *A. spinosa* Davies and Pinfold, *A. subspinosa* Davies and Pinfold, *A. laminosa* Gill, *A. granulosa* (d'Archiac), *A. placentula* (Deshayes), *L.tipperi* (Davies) and *L. conditi* (Nuttall) along with *Alveolina* sp.

**Depositional Settings:** The shallow shelf facies was the chief mode of sedimentation of the Early Eocene Chor Gali Formation. The principal mode of carbonate sedimentation of the Chor Gali Formation was depending upon the accumulation of organically derived particles (larger benthic foraminifera, algae and gastropods). In the present study, the environmental conditions that originally prevailed during the deposition of the Chor Gali Formation were based on its facies associations, fossil contents and palaeoecological factors.

The microfacies associations identified in the shallow shelf facies of the Chor Gali Formation in the study area included the following types: bioclastic mudstone, bioclastic mudstone to wackestone, bioclastic wackestone, bioclastic packstone and bioclastic grainstone. The detailed sedimentological studies revealed that the deposition of mudstone was indicative of low energy quite water conditions. There was abundance of micrite which suggested that currents were not strong enough to remove the mud. The packstone and the wakestone showed moderate energy environment. The grainstone represented deposition in high energy conditions.

The study of larger benthic foraminifera revealed nine age diagnostic species; *N. mamillatus* (Fichtel and Moll), *N. atacicus* Leymerie, *A. spinosa* Davies and Pinfold, *A. subspinosa* Davies and Pinfold, *A. laminosa* Gill, *A. granulosa* (d'Archiac), *A. placentula* (Deshayes), *L. tipperi* (Davies) and *L. conditi* (Nuttall). *Nummulites* which were the important contributors in shelf-ramp facies in many Paleogene successions (Aigner, 1983; Racey, 2001; Beavington and Racey, 2004; Beavington *et al*., 2005). *Nummulites* associated with *Assilinas* were assigned either deep or shallow water shelf environments. In the Chor Gali Formation abundance of small lenticular *Nummulites* associated with *Assilinas* were indicative of shallow water facies in shallow shelf environments ( Beavington, 2004). The foraminifera distributed throughout the Chor Gali Formation justify Early Eocene age of Tertiary times (Warwick and Shakoor, 1993; Hottinger, 1998; Cosovic et al., 2004; Barattolo *et al*., 2007).The detailed microfacies analysis and presence of age diagnostic larger benthic forminifera suggested shallow shelf marine environment or in other words the Chor Gali Formation could be designated as carbonate platform deposition in the Tethyan realm ((Buxton and Pedley, 1989; Hottinger,1998; Cosovic *et al*., 2004; Barattolo *et al*., 2007) Fig. 9.

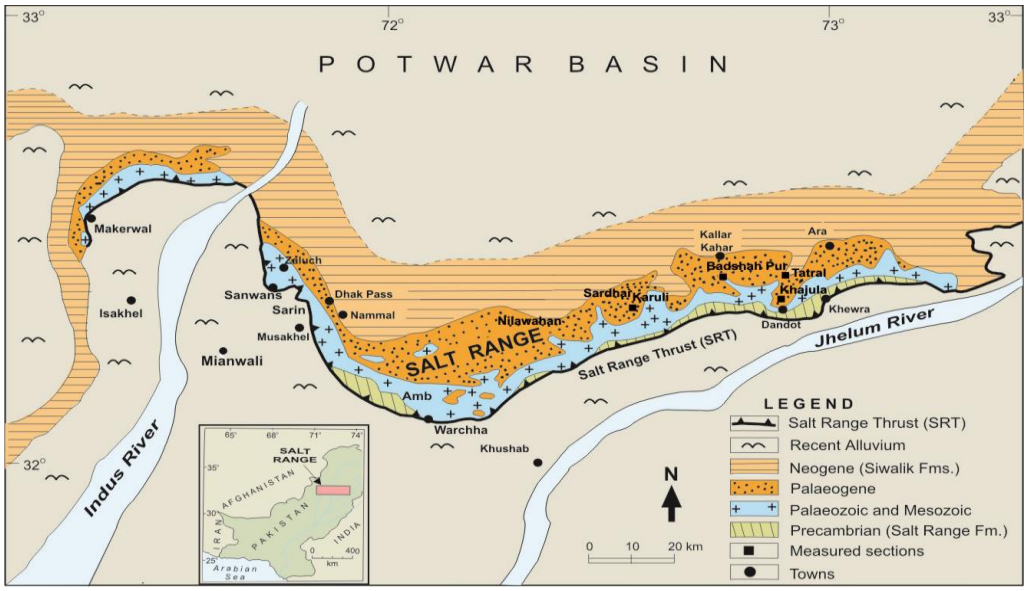


**Fig-1. Showing location map of the study area, showing measured sections of the Chor Gali Formation, Central Salt Range, Pakistan.**

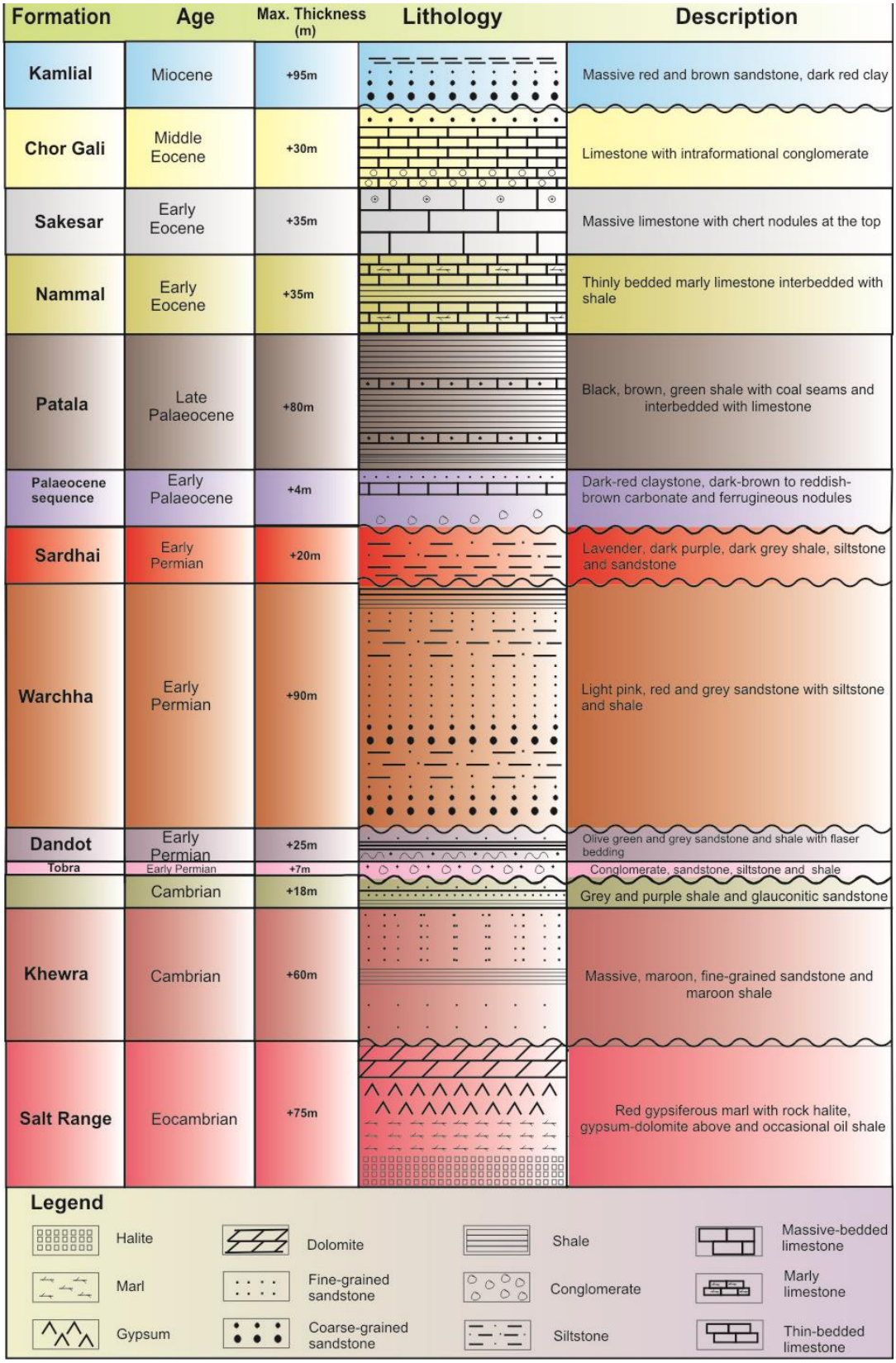


**Fig-2. Showing exposed stratigraphic successions in the Central Salt Range, Pakistan (Modified after Ghazi and Mountney, 2009).**

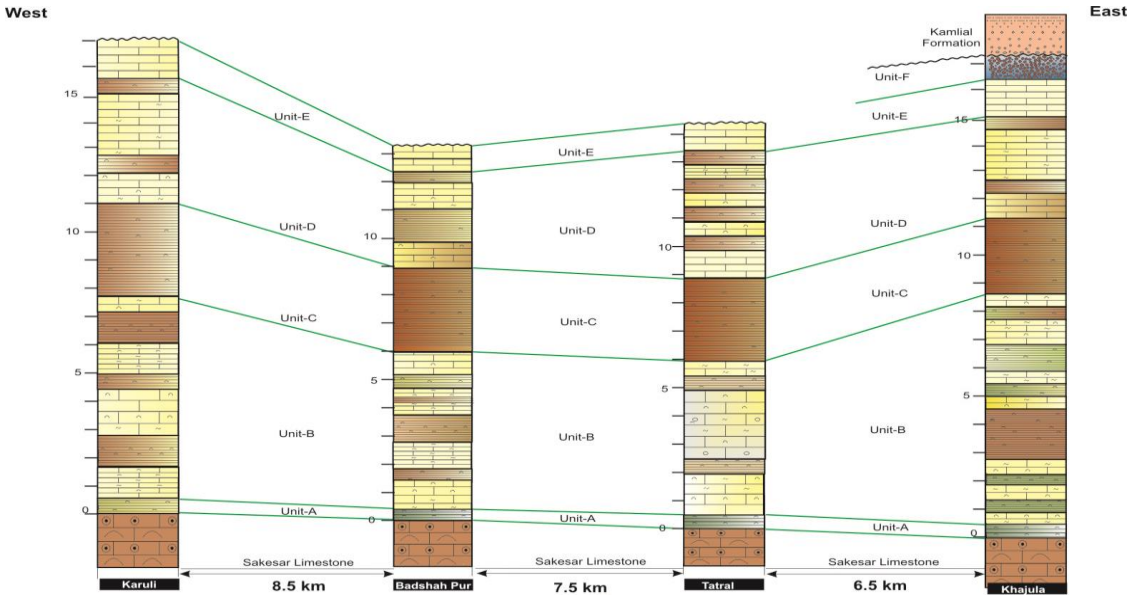


**Fig-3. Showing lithostratigraphic correlation of the Chor Gali Formation of Khajula, Tatral, Badshah Pur and Karuli, Central Salt Range, Pakistan.**

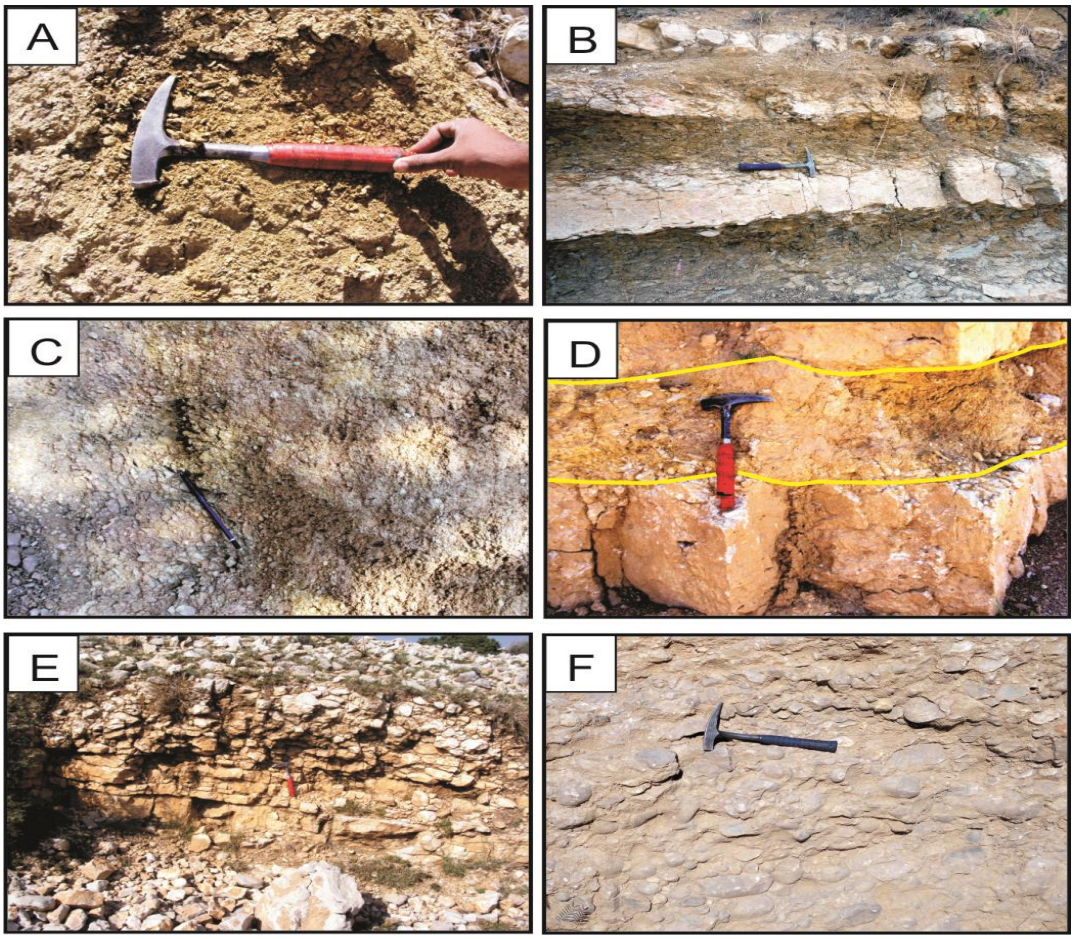


**Fig-4. Showing outcrop exposures of the lithostratigraphic units recorded in the Chor Gali Formation, Central Salt Range, Pakistan. A) Greenish-grey shale unit at the basal parts of the formation. B) Alternate thin-bedded limestone and shale unit. C) Greenish-grey to reddish green shale unit. D) Highly fossiliferous shale in alternate limestone and shale unit. E) Argillaceous limestone unit. F) Intrabasinal conglomerate unit at the top of the formation.**

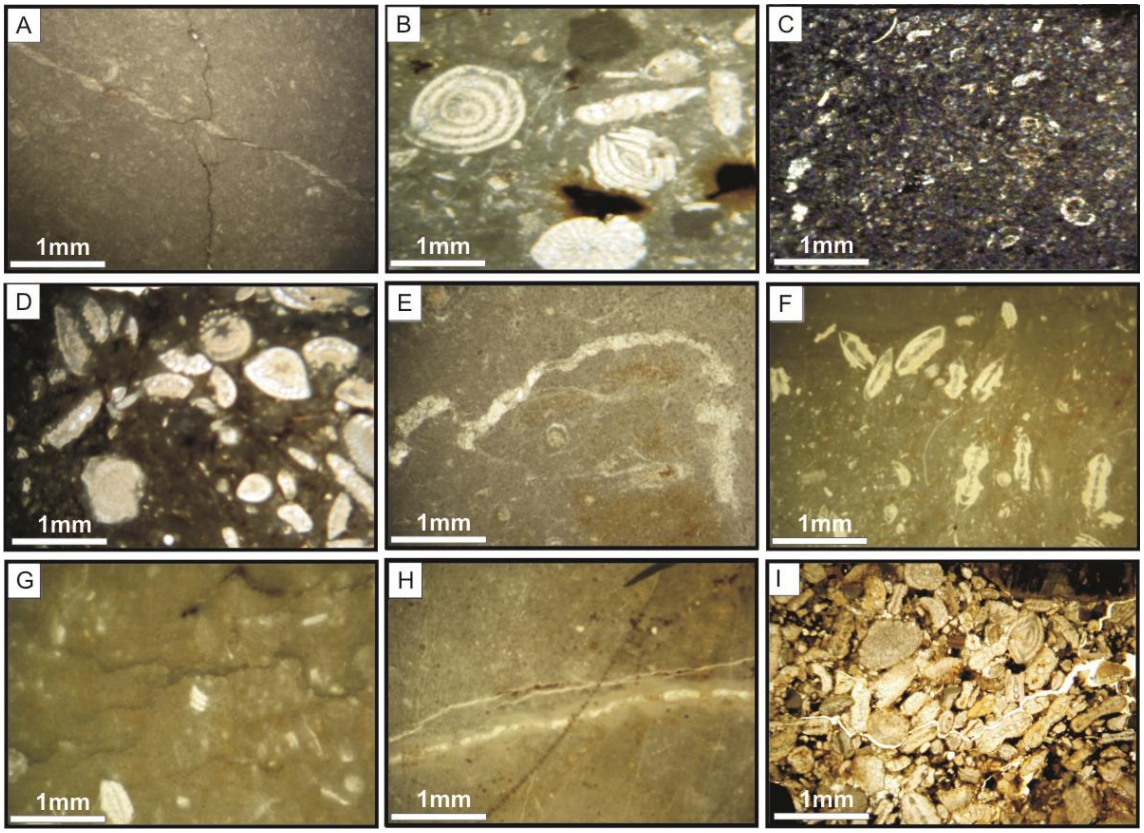


**Fig-5. Photomicrographs showing main facies in the Chor Gali Formation, Central Salt Range, Pakistan. A) Bioclastic mudstone facies, showing calcite vein. B) Bioclastic wackestone facies. C) Bioclastic mudstone facies. D) Bioclastic packstone facies having species of *Assilina* and *Nummulites*. E) Bioclastic mudstone facies showing stylolite with high amplitude. F) Bioclastic mudstone to wackestone facies with prominent bioclasts of *Assilina* sp. G) Bioclastic mudstone facies with branching out pattern of stylolites. H) Calcite veins in stylobedded mudstone. I) Bioclastic grainstone facies with intergranular calcite cement.**

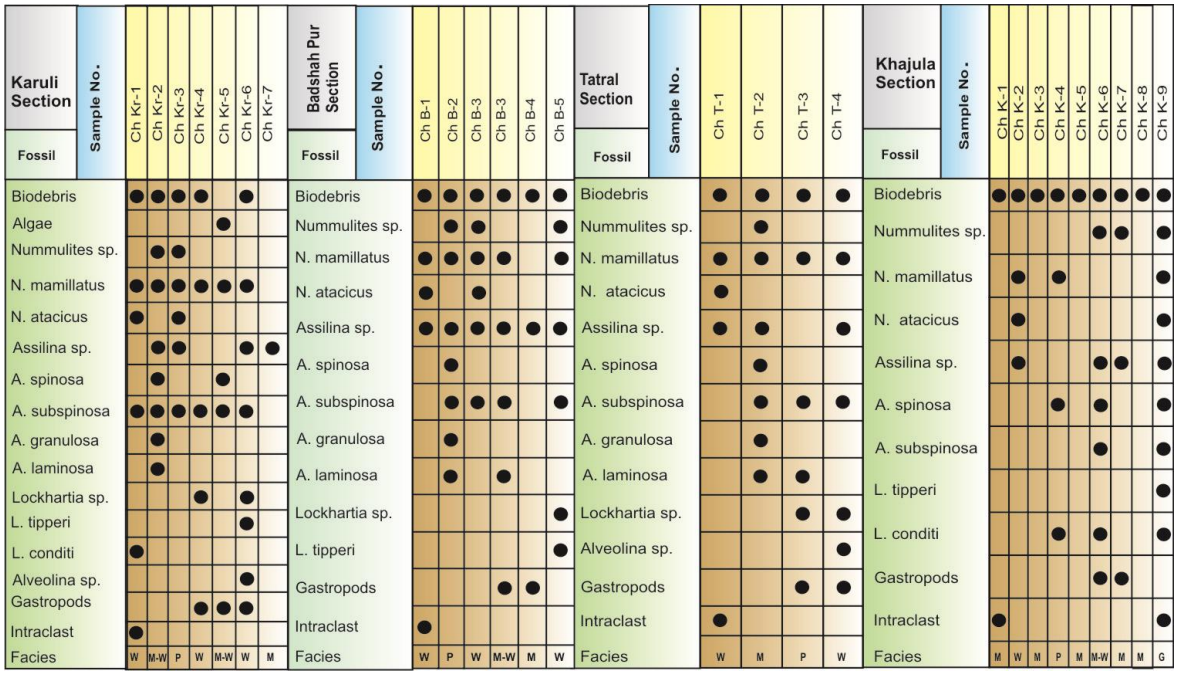


**Fig-6. Showing distribution chart of larger benthic foraminifera in the Early Eocene Chor Gali Formation, Central Salt**

**Range.**

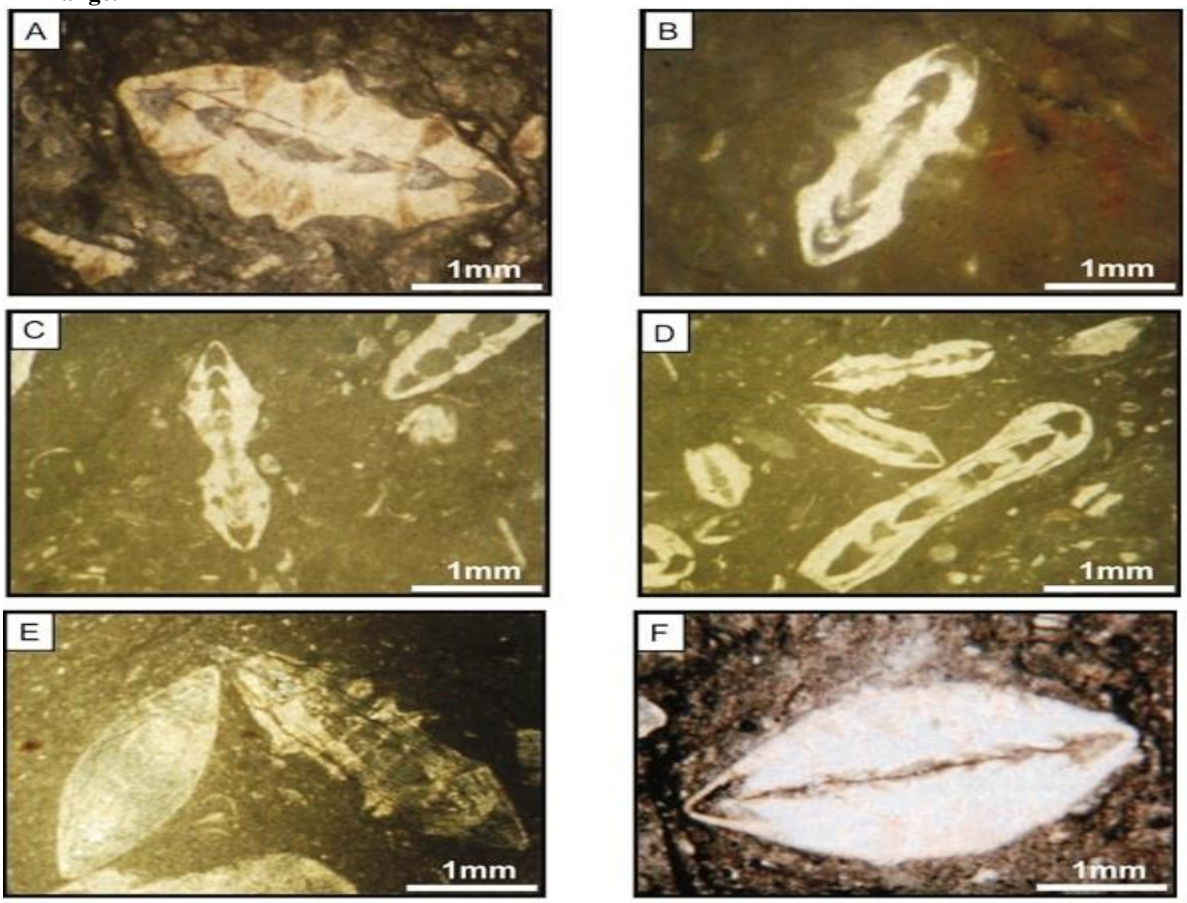


**Fig-7. Photomicrographs showing different species of *Assilina* in the Chor Gali Formation, Central Salt Range, Pakistan. A) *Assilina subspinosa* Davies and Pinfold, B, C) *Assilina spinosa* Davies and Pinfold, D) *Assilina placentula* (Deshayes), E) *Assilina granulosa* (d'Archiac), F) *Assilina laminosa* Gill.**

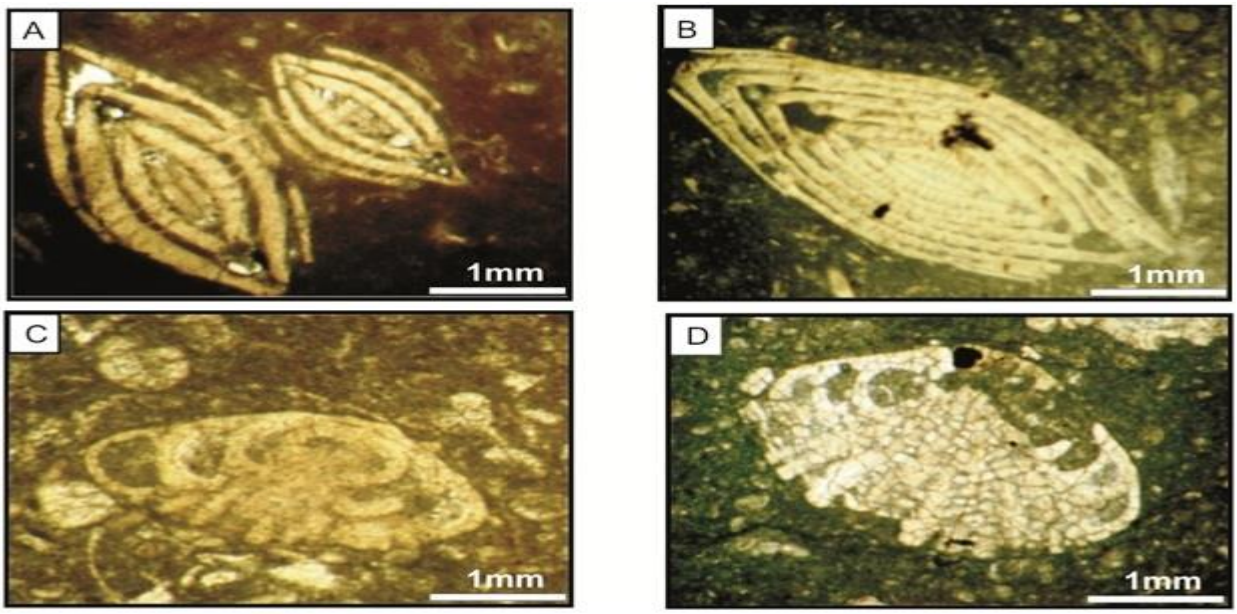


**Fig-8. Photomicrographs showing different species of *Nummulites* and *Lockhartia* in the Chor Gali Formation, Central Salt Range, Pakistan. A) *Nummulites mamillatus* (Fichtel and Moll), B) *Nummulites atacicus* Leymerie, C) *Lockhartia***

***tipperi* (Davies), D) *Lockhartia conditi* (Nuttall).**

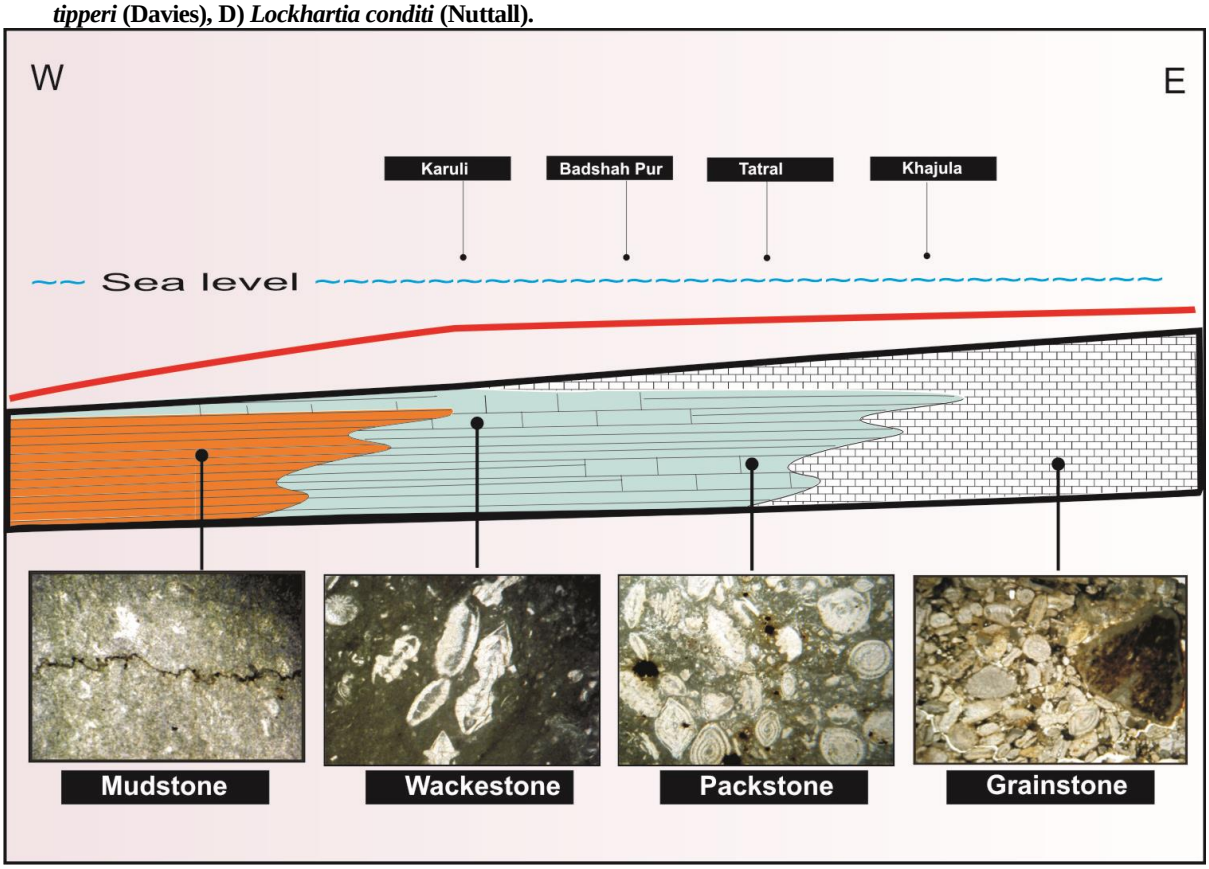


**Fig-9. Showing schematic profile of the important lithofacies encountered in the Chor Gali Formation, Central Salt Range, Pakistan. Not to scale.**

**Conclusions:** Six dominant litho-units were established in the Chor Gali Formation based on the field observations. Total of nine microfacies have been described from four measured stratigraphic sections of Karuli, Tatral, Badshah Pur and Khanjula, which mainly included bioclastic mudstone, bioclastic wackestone, bioclastic packstone and bioclastic grainstone. Age diagnostic larger benthic foraminifera of *Nummulites*, *Assilina* and *Lockhartia* were identified. Microfacies studies and abundance of larger benthic foraminifera in the Chor Gali Formation represented inner neritic shallow shelf environment.

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