LARGER BENTHIC FORAMINIFERAL ASSEMBLAGE FROM THE EARLY EOCENE CHOR GALI FORMATION, SALT RANGE, PAKISTAN

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Abstract: *The ascending order of the Early Eocene carbonate succession of the Salt Range, Pakistan is composed of three distinct units: Nammal Formation, Sakesar Limestone and Chor Gali Formation. The present work is focused only on the foraminiferal assemblage of the Chor Gali Formation from the Salt Range. The Chor Gali Formation is predominantly composed of thin to well bedded limestones, shales and marls, rich in larger benthic foraminifers (LBF). The present study is based on four stratigraphically important sections: Karuli, Badshah Pur, Tatral and Khajula. Eighty thin sections were prepared that contained LBF species: Nummulites mamillatus (Fichtel and Moll), Nummulites atacicus Leymerie, Assilina spinosa Davies and Pinfold, Assilina subspinosa Davies and Pinfold, Assilina laminosa Gill, Assilina granulosa (d'Archiac), Assilina placentula (Deshayes), Lockhartia tipperi Davies, Lockhartia conditi (Nuttall) and Alveolina sp. The presence of shallow water LBF assemblage reveals inner-shelf depositional environment for the Chor Gali Formation.*

Keywords: Early Eocene, Chor Gali Formation, larger benthic foraminifera, inner shelf, Salt Ranges, Pakistan

INTRODUCTION

The Salt Range is a classical locality in Pakistan stratigraphy because its geological exposure of varying ages can be examined through number of gorges offering varied geological studies in view of its easy accessibility. The Salt Range forms the Southern border of the adjoining hydrocarbon bearing Potwar Basin and dipping normally towards the basin. The east-west trending mountainous belt is designated Salt Range between the River Jhelum in the east and the River Indus in the west, while the north south trending belt beyond River Indus at Kala Bagh is known as the Trans Indus Salt Range (Fig. 1).

The term "Chor Gali Beds" of Pascoe (1920) formalized as Chor Gali Formation by the Stratigraphic Committee of Pakistan (Fatmi, 1973) after the Chor Gali Pass in the Khair-e-Murat Range (Lat. 33°26' 30"N; Long. 70°41'E), Potwar Basin. The Chor Gali Formation is mainly composed of shale and limestone. The lower part of the formation is shale of greenish-grey color which is soft and calcareous, the well-bedded argillaceous limestone which is yellowish and greenish grey in color comprised the upper part of the formation (Abbas, 1989). It conformably overlies the Sakesar Limestone (Early Eocene) and unconformably overlain by the Kamlial Formation (Miocene) in the Salt Range. In the Salt Range it forms low ridges and gentle slopes as compared to the Sakesar Limestone which is known for steep cliffs (Abbas, 1989).

Davies and Pinfold (1937) described the stratigraphy of the Palaeocene-Early Eocene succession of the Salt Range and illustrated age diagnostic larger benthic foraminiferal assemblage. Gill (1953) described and illustrated the various species of the foraminiferal genus *Assilina* from the Salt Range. However, Gill (1953) described *Assilina* granulosa (d'Archiac), *Assilina leymerie* (d'Archiac) and *Assilina daviesi* de Cizancourt from the Chor Gali Formation.

The present study is focused to discuss the present species of LBF and the depositional setting of the Early Eocene Chor Gali Formation.

GEOLOGICAL SETTING

The Salt Range possesses a unique tectonic setting. The youngest and highest mountain orogeny namely Himalayan Orogeny is a result of continent to continent collision between northward drifting Indo-Pak plate and southward drifting Eurasian plate, (Warwick and Wardlaw, 1992). The collision took place nearly 55ma ago.

The closure of Neo-Tethys and rise of the Himalayas resulted in different stratigraphic sequences (Warwick and Wardlaw, 1992). During the Himalayas orogeny, series of parallel regional thrust faults developed with north dipping and south verging trend. The southernmost, Himalayan Frontal Thrust (HFT) and Main Boundary Thrust (MBT) are active while the regional thrusts in the north are locked 15 million years ago (Le Fort, 1975).

The Salt Range is a surface exposure along the HFT, locally called Salt Range Thrust (SRT) possessed leading edge of the decollement thrust that resulted from

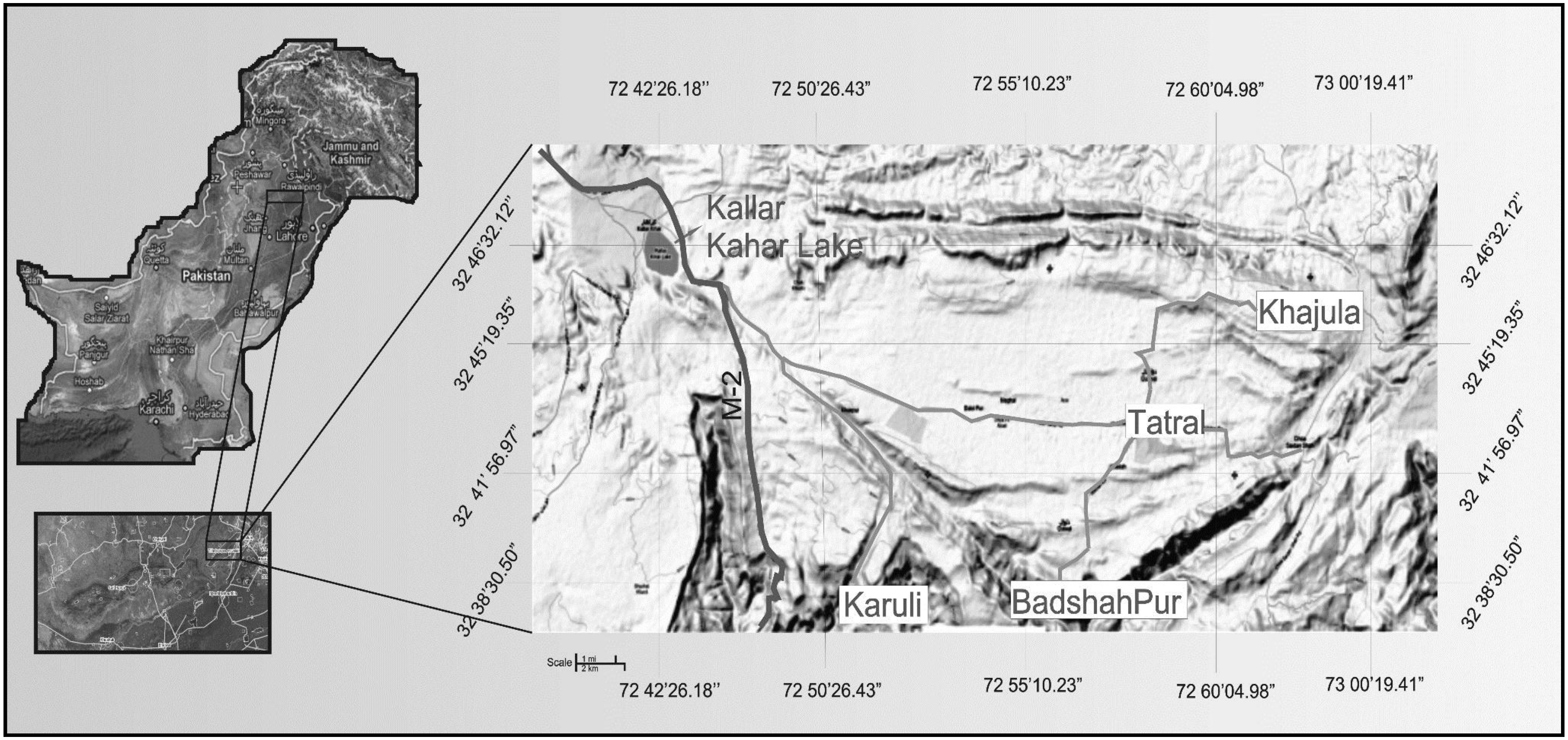

Fig. 1 Location map of the study area, showing various measured stratigraphic sections (Karuli, Badshah Pur, Tatral and Khajula) of the Early Eocene Chor Gali Formation, Salt Range, Pakistan

sediment decoupling from the northward drifting basement of Indian shield. It's the external and most recent expression of Himalayan continental shortening. SRT is thin-skinned fold and thrust belt in which Paleozoic to Recent sediments are shortened above a ductile substrate of thick Eo-Cambrian evaporites of the Salt Range Formation (Lillie, *et al.*, 1987).

MATERIALS AND METHODS

The Chor Gali Formation has been sampled from Karuli, Badshah Pur, Tatral and Khajula sections in the Salt Range (Fig. 1). A total of 80 thin sections were prepared to identify the faunal assemblage. LBF have been found in abundance throughout the formation with good preservation. Complete bottom to top association of these foraminifera for each section is studied. Samples were mainly collected from limestone units of the formation.

Larger Benthic Foraminifera

According to Hottinger (2001) the Early Eocene represents the phase 3 of the global community maturation cycle. This phase represents the sudden diversification of numerous species and indicative of complete recovery of larger foraminifera in the Salt Range region after the Cretaceous/Palaeogene (KP) boundary collapse. In this region the KP boundary is marked as palaeoenvironmnetal indicator including higher temperature and oligotrophic conditions that caused the dominance of LBF after the demise of corals (c.f. Daoud, 2009, Scheibner and Speijer, 2008 and Scheibner, *et al.*, 2005).

RESULTS AND DISCUSSIONS

The larger benthic foraminifers are the dominant distributed biota in the Chor Gali Formation. The following LBFs are recorded and their distribution through all the studied sections is given in Fig. 2.

Genus: *Nummulites* Lamarck, 1801

***Nummulites mamillatus* (Fichtel and Moll) (Figs. 3A, 3B)**

1798. *Nautilus mamilla* Fichtel and Moll, 'Testacea Microscopica', p. 53-54; pl. 6, Figs. a-d

1987. *Nummulites mamillatus* (Fichtel and Moll). Butt, Acta. Mineralogica Pakistanica, Vol. 3, p. 97-110, Figs. 7(D-E)

1991. *Nummulites mamillatus* (Fichtel and Moll). Butt, Micropaleontology, 37(1), pl. 4, Fig. d

1999. *Nummulites mamillatus* (Fichtel and Moll).Butt and Akhtar, Revue de Paléobiologie, 18 (1), p. 134, pl. 5, Fig. 1

Remarks: This specimen is characterized by strongly biconvex shell with thick wall, narrowly spaced chambers and umbonal pillars in the cross section. *Nummulites mamillatus* (Fichtel and Moll) and *Nummulites globulus* Leymerie appears as same species. However the topotype material of both species should be examined to determine the actual taxonomy.

***Nummulites atacicus* Leymerie (Figs. 3C, 3D)**

1846. *Nummulites atacicus* Leymerie, Memoirs of the Geological Society of France, Vol. I (2), p. 358-359; pl. 13, Figs. 13a-13e

1937. *Nummulites atacicus* Leymerie, Davies and Pinfold, Geological Survey of India Memoir, Paleontogica Indica, New Series, Vol. 24, p. 24-25, pl. 3, Figs. 4, 8 and 10

1976. *Nummulites atacicus* Leymerie; Latif, Geological Bulletin of the Punjab University, No. 13, p. 36, pl. 141. Fig. d

1987. *Nummulites atacicus* Leymerie; Butt, Acta Mineralogica Pakistanica, Vol. 3, p. 97-110, Fig. 7(D-E)

Remarks: Our specimens resemble with the type species.

Genus *Assilina* d'Orbigny, 1826

***Assilina subspinosa* Davies and Pinfold (Figs. 3E, 3F)**

1937. *Assilina subspinosa* Davies and Pinfold, Geological Survey of India, Paleontologica Indica, New Series, Vol. 24, Memoir 1. p. 33-34, pl. 4, Figs. 19-20, 23-26

1976. *Assilina subspinosa* Davies and Pinfold; Latif, Geological Bulletin of the Punjab University, No. 13, p. 34-35, pl. 11. Fig. 3

1987. *Assilina subspinosa* Davies and Pinfold; Butt, Acta Mineralogical Pakistanica, Vol. 3, p. 97-110, Fig. 8(A)

1999. *Assilina subspinosa* Davies and Pinfold; Butt and Akhtar, Revue de Paléobiologie, 18 (1), p. 136, pl. 5, Figs. 3-4; pl. 6, Fig. 4

Remarks: *Assilina subspinosa* and *Assilina spinosa* of Davies and Pinfold (1937) are ornamented with granules which give spinose appearance. *Assilina subspinosa* lack central depression and this feature differentiate it from *Assilina spinosa.* These species can also be distinguished by their stratigraphic ranges as *Assilina spinosa* is characteristics of Early Eocene while *Assilina subspinosa* ranges from Upper Palaeocene to Early Eocene.

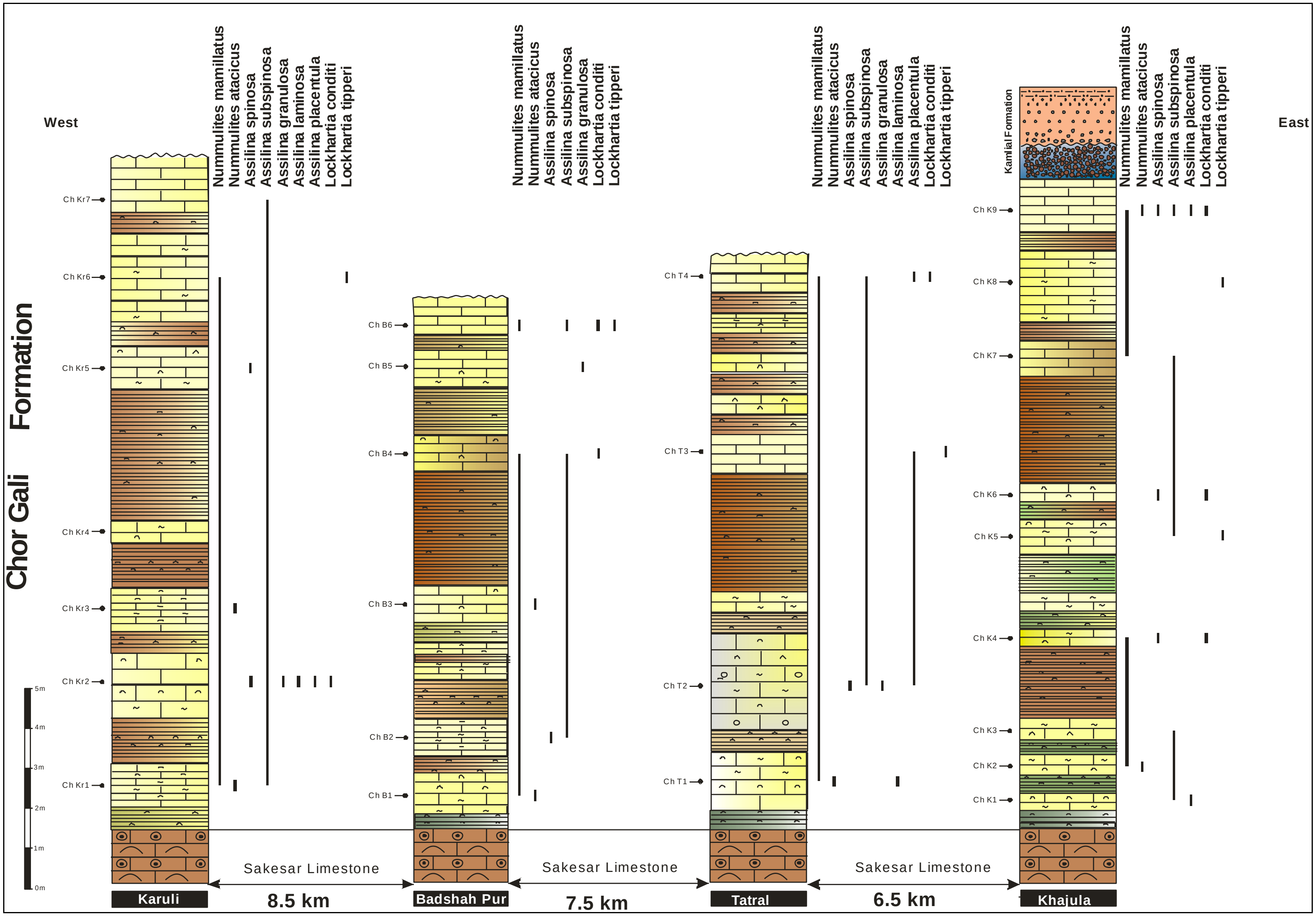

Fig. 2 Foraminiferal Distribution Chart of the Early Eocene Chor Gali Formation from four Measured Sections, Salt Range, Pakistan

***Assilina spinosa* Davies and Pinfold (Figs. 3G, 3H)**

1937. *Assilina spinosa* Davies and Pinfold, Geological Survey of India Memoir, Paleontogica Indica, New Series, Vol. 24, Memoir 1, p. 31-33, pl. 4, Figs. 11-12, 16-17

1976. *Assilina spinosa* Davies and Pinfold; Latif, Geological Bulletin of the Punjab University, No. 13, p. 35, pl. 11. Fig. 2

1999. *Assilina spinosa* Davies and Pinfold; Butt and Akhtar, Revue de Paléobiologie, 18 (1), p. 136, pl. 6, Fig. 3

Remarks: *Assilina spinosa* Davies and Pinfold is distinguished from *Assilina subspinosa* Davies and Pinfold by its central depression in addition to having their different stratigraphic ranges.

***Assilina laminosa* Gill (Fig. 4A)**

1953. *Assilina laminosa* Gill; Gill, Contributions of Cushman Foundation, Foraminiferal Research, Vol. 4, Pt. 2, p. 83, pl. 13, Fig. 15

1987. *Assilina laminosa* Gill; Butt, Acta Mineralogical Pakistanica, Vol. 3, p. 97-110, Fig. 7 C

1999. *Assilina laminosa* Gill; Butt and Akhtar, Revue de Paléobiologie, 18 (1), p. 136, pl. 4, Figs. 3

Remarks: *Assilina laminosa* Gill is characterized by internally laminated shell wall. It is diagnostic of the Early Eocene strata.

***Assilina granulosa* (d'Archiac) (Fig. 4B)**

1848. *Nummulites granulosa* d'Archiac (pars); d'Archiac, Geological Society of France Memoir (2), Vol. 3, p. 415-416; pl. 9, Fig. 21

1853. *Nummulites granulosa* d'Archiac (pars); d'Archiac and Haime, 'Descer. An. foss. Gr. numm. Inde', p. 151-153, 181; Pl. 10, Figs. 11-12, 16-17

1937. *Assilina granulosa* (d'Archiac); Davies and Pinfold, Geological Survey of India, Paleontolgical Indica, New Series, Vol. 24, Memoir 1, p. 29-31, pl. 4, Figs. 4-5, 9-10

1959. *Assilina granulosa* (d'Archiac); Nagappa, Micropaleontology. Vol. 5, No. 2, p. 145-192, pl. 8, Figs. 4-6

1987. *Assilina granulosa* (d'Archiac); Butt, Acta Mineralogical Pakistanica, Vol. 3, p. 97-110, Fig. 7a

1999. *Assilina granulosa* (d'Archiac); Butt and Akhtar, Revue de Paléobiologie, 18 (1), p. 136, pl. 6, Figs. 1-2; pl. 7, Fig. 6

Remarks: *Assilina granulosa* (d'Archiac) is characterized by heavily granulated surface with distinct septal ridges.

Assilina placentula (Deshayes) (Fig. 4C)

1838. *Assilina placentula* (Deshayes); Verneuli and Deshayes, Geological Society of France Memoirs, Paris, Vol. 3, pt. 1, No. 1-2, pp. 1-69, pl. 6, Fig. 9

1904. *Assilina placentula* (Deshayes); Prever and Rzehak, Naturf. Ver. Brunnn, Vreh., Brunn, Austria, Vol. 42 (1903), pp. 190-201, pl. 1, Figs. 1-8

1951. *Assilina placentula* (Deshayes); Schaub, Paleontology Abh. (Memmoir Suisses Paleontology), Basel, Switzerland, Vol. 68, pp. 1-222, pl. 8, Figs. 17-19; pl. 9, Figs. 1-8, 11; p. 207, tfs. 313-318; p. 211, tf. 319

1960. *Assilina placentula* (Deshayes); Nemkov and Barkhatova, Ministry of Special Education, SSSR, Moscow, Higher Education Institute, Izvestia, Geology and Prospection Fascination, 5, pp. 29-43, pl. 4, Figs. 11-15

Remarks: *Assilina placentula* (Deshayes) is a planar form with slight central depression having smooth surface.

Genus: *Lockhartia* Davies, 1932

***Lockhartia conditi* (Nuttall) (Figs. 4D, 4E)**

1926. *Dictyoconoides conditi* Nuttall, Geological Magazine, London, Vol. 63, p. 119, 498; pl. 11, Figs. 7-8

1937. *Lockhartia conditi* (Nuttall); Davies and Pinfold, Geological Survy of India Memoir, Paleontologica Indica, New Series, Vol. 24, Memoir 1, p. 47-48, pl. 5, Fig. 24

1954. *Lockhartia conditi* (Nuttall); Smouts, British Museum of Natural History, UK, pp. 55-56, pl. V, Figs. 16-19

1987. *Lockhartia conditi* (Nuttall); Butt, Acta. Mineralogica Pakistanica, Vol. 3, p. 97-110, Fig. 8(A)

1999. *Lockhartia conditi* (Nuttall); Butt and Akhtar, Revue de Paléobiologie, 18 (1), p. 132, pl. 3, Figs. 1-2

Remarks: *Lockhartia conditi* (Nuttall) is represented by high trochospiral shell with few thick pillars on the umbilical side. *Lockhartia conditi* (Nuttall) is distinguished from *Lockhartia tipperi* (Davies) by its high trochospiral shell. This species ranges from Palaeocene to Early Eocene.

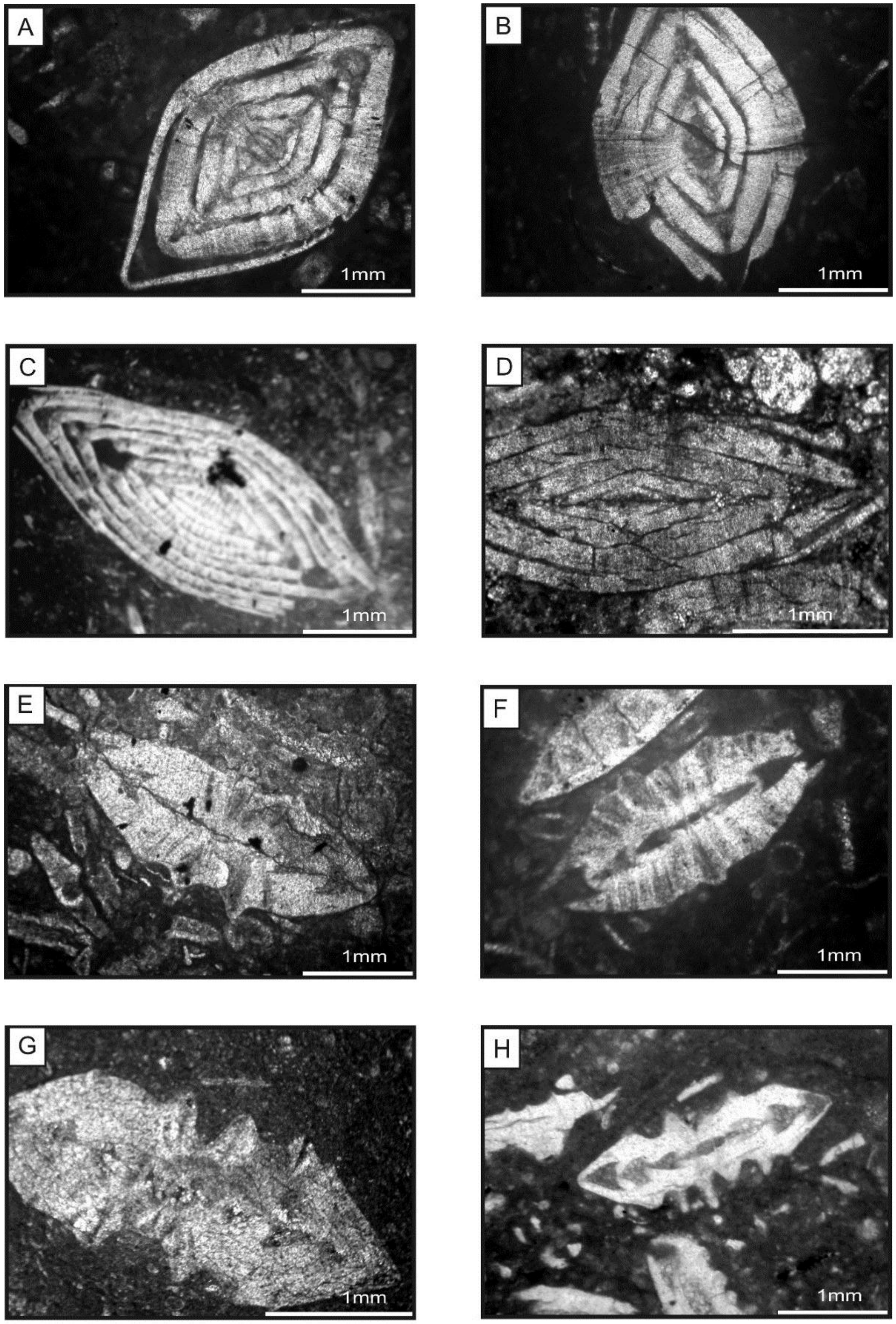

Fig. 3 Photomicrographs showing important foraminifers: A and B) *Nummulites mamillatus* (Fichtel and Moll), C and D) *Nummulites atacicus leymerie*, E and F) *Assilina subspinosa* Davies and Pinfold, G and H) *Assilina spinosa* Davies and Pinfold, collected from the Chor Gali Formation, Salt Range, Pakistan.

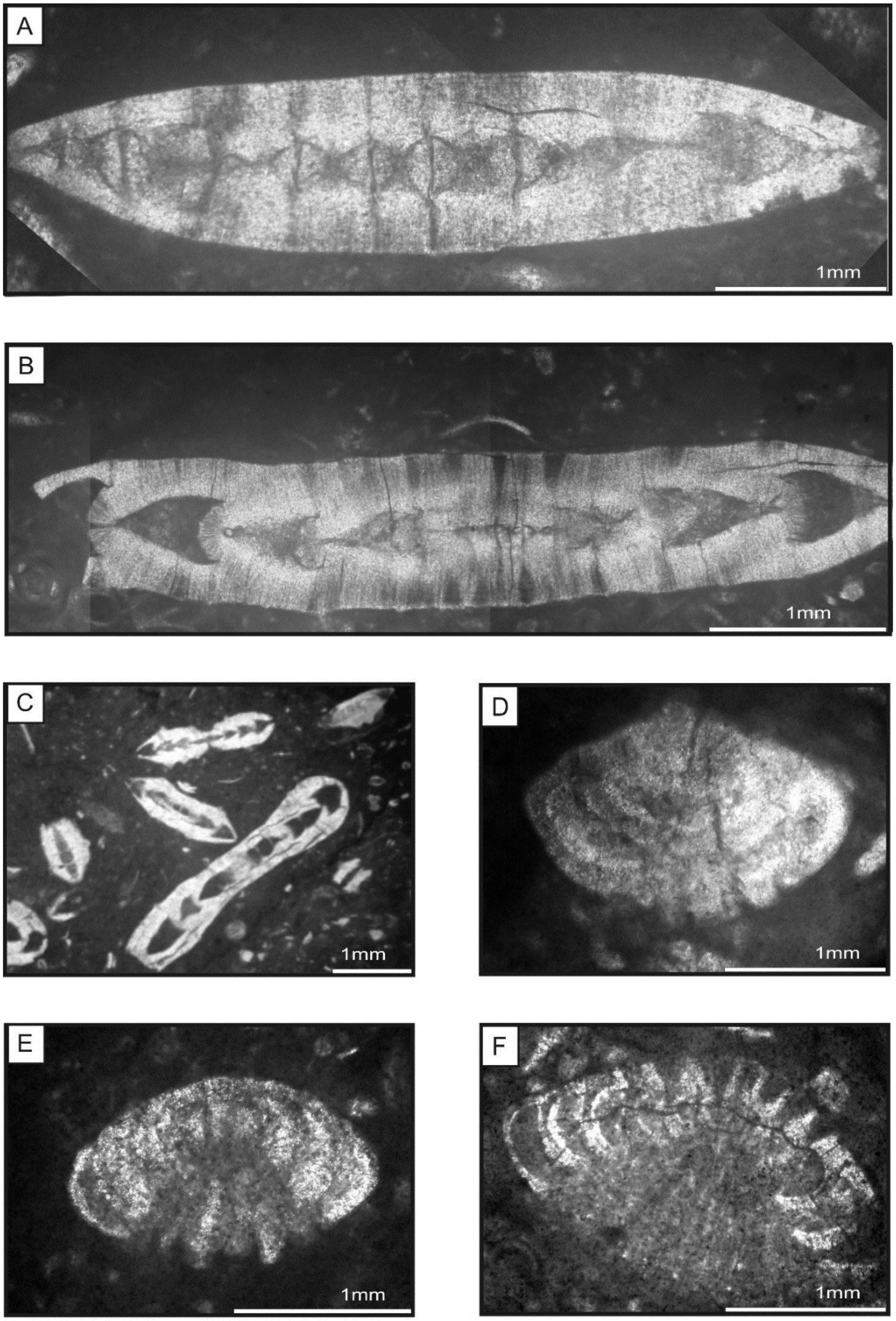

Fig. 4 Photomicrographs showing important foraminifers: A) *Asslina laminosa* Gill, B) *Asslina granulosa* (d'Archiac), C) *Assilina placentula* (Deshayes), D and E) *Lockhartia conditi* (Nuttall) and F) *Lockhartia tipperi* (Davies) collected from the Chor Gali Formation, Salt Range, Pakistan.

Lockhartia tipperi **(Davies) (Fig. 4F)**

1926. *Conulites tipperi* Davies, Geological Survey of India, Records, 59, p. 247-248; pl. 18, Fig. 8

1937. *Lockhartia tipperi* (Davies); Davies and Pinfold, Geological Survey of India, Mineralogical Indica, New Series, Vol. 24 No. 1, p. 48-49, pl. 6, Figs. 14-16, pl. 7, Fig. 17

1954. *Lockhartia tipperi* (Davies); Smout, British Museum of Natural History, p. 55, pl. 4, Figs. 11-13

1987. *Lockhartia tipperi* Davies; Butt, Acta Mineralogica Pakistan, Vol. 3, p. 97-110, Fig. 6(E)

1999. *Lockhartia tipperi* (Davies); Butt and Akhtar, Revue de Paléobiologie, 18 (1), p. 132, pl. 4, Fig. 4

Remarks: *Lockhartia tipperi* (Davies) is characterized by low trochospiral shell with rounded peripheral margin and umbilical pillars. This species has stratigraphic range from Late Palaeocene to Early Eocene.

The species *Assilina Leymerie* (d'Archiac) recorded by Gill (1953) from the Chor Gali Formation in the Salt Range corresponds to shallow benthic zone 8 (Serra-Kiel, *et al.*, 1988). Sameeni and Butt (2004) have assigned SBZ 9 to the Chor Gali Formation based on Alveolinid biostratigraphy but in the present study authors have found very few specimens of *Alveolina* that are not identified upto species level. In the present study the foraminiferal assemblage found in the Chor Gali Formation include *Nummulites mamillatus* (Fichtel and Moll), *Nummulites atacicus* Leymerie, *Assilina spinosa* Davies and Pinfold, *Assilina subspinosa* Davies and Pinfold, *Assilina laminosa* Gill, *Assilina granulosa* (d'Archiac), *Assilina placentula* (Deshayes), *Lockhartia tipperi* (Davies), *Lockhartia conditi* (Nuttall) and *Alveolina sp*. According to Serra-Kiel, *et al.* (1988) *Nummulites atacicus* Leymerie corresponds to shallow benthic zone 8 (SBZ 8) and *Assilina placentula* (Deshayes) indicates SBZ 10. Presence of above mentioned LBF species substantiate the Early Eocene age (Late Ilerdian to Early Cusian) to the Chor Gali Formation.

Moreover the presence of larger benthic foraminifers clearly suggesting inner neritic shelf zone and reflect a shallow marine environment of deposition for the Chor Gali Formation during Early Eocene (Ghazi, *et al.*, 2006 and Luterbacher, 1984).

CONCLUSIONS

The Early Eocene Chor Gali Formation contains a variety of stratigraphically important LBF species substantiating the age evaluation. The presence of larger benthic foraminifera indicates that the Chor Gali Formation has been deposited in the inner neritic (shallow shelf) environments representing carbonate platform setting.

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