ISSN: 0067-2904

Biostratigraphy of the Upper Cretaceous Fort Munro Formation, Rakhi Gorge, Eastern Sulaiman Range, Pakistan

Arslan Zaheer[1], Shahid Ghazi[1], Mubashir Mehmood*[2], Muhammad Yaseen[2], Muhammad Jehangir Khan[1], Umair Sarwar[1]
[1]*Institute of Geology, University of the Punjab, Lahore*
[2]*Department of Geology, Abdul Wali Khan University Mardan*

Received: 23/10/2020 Accepted: 12/7/2021 Published: 30/7/2022

Abstract

The Fort Munro Formation is well exposed along DG Khan-Fort Munro road, a type locality. The section was measured and sampled for the biostratigraphy, where it has a conformable lower contact with Mughalkot Formation and is underlain by the Pab Sandstone. The total observed thickness was 105 meters, and 26 samples were collected from top to the bottom at random intervals. Fifty thin sections were studied carefully, and five species of large benthic foraminifera, including *Orbitoidestissoti, Orbitoidesapiculata, Orbitoides media, Orbitoideshottingeri,* and *Omphalocyclusmacroporus* were identified along with miliolids. Gastropods, Bivalves and Echinoderms were also observed. Based on identified microfossils, the depositional environment of the formation is the inner ramp to the middle ramp deposited in the Campanian to Maastrichtian age.

Keywords: *Fort Munro, Biostratigraphy, Orbitoides, Omphalocyclus, Sulaiman Range Pakistan.*

Introduction

The Middle Indus basin of Pakistan hosts significant and most attractive exposures of the Cretaceous Formations. Fort Munro Formations is part of the Middle Indus basin excellently exposed in the Rakhi Gorge section. Williams [1] called the formation as Fort Munro Limestone; later on, after the amendment by Shah [2] [3], the strata was called Formation because it has its characters and geographical distribution. The Formation is visible in Sulaiman and Kirther province and the Quetta region (Axial belt) [3]. The type locality of the Fort Munro Formation is on the western limb of the Fort Munro anticline that is located on the Dg khan- Fort Munro Road and bounded between N 29°8′00.1″, E 70°04′46.2″ and N 29°57′56.3″, E 70°3′38.7″. A map of the study area and Route to Fort Munro is shown in (Figures 1-2). The type locality was designated by Williams [1].

*Email: mubashirmehmood94@gmail.com

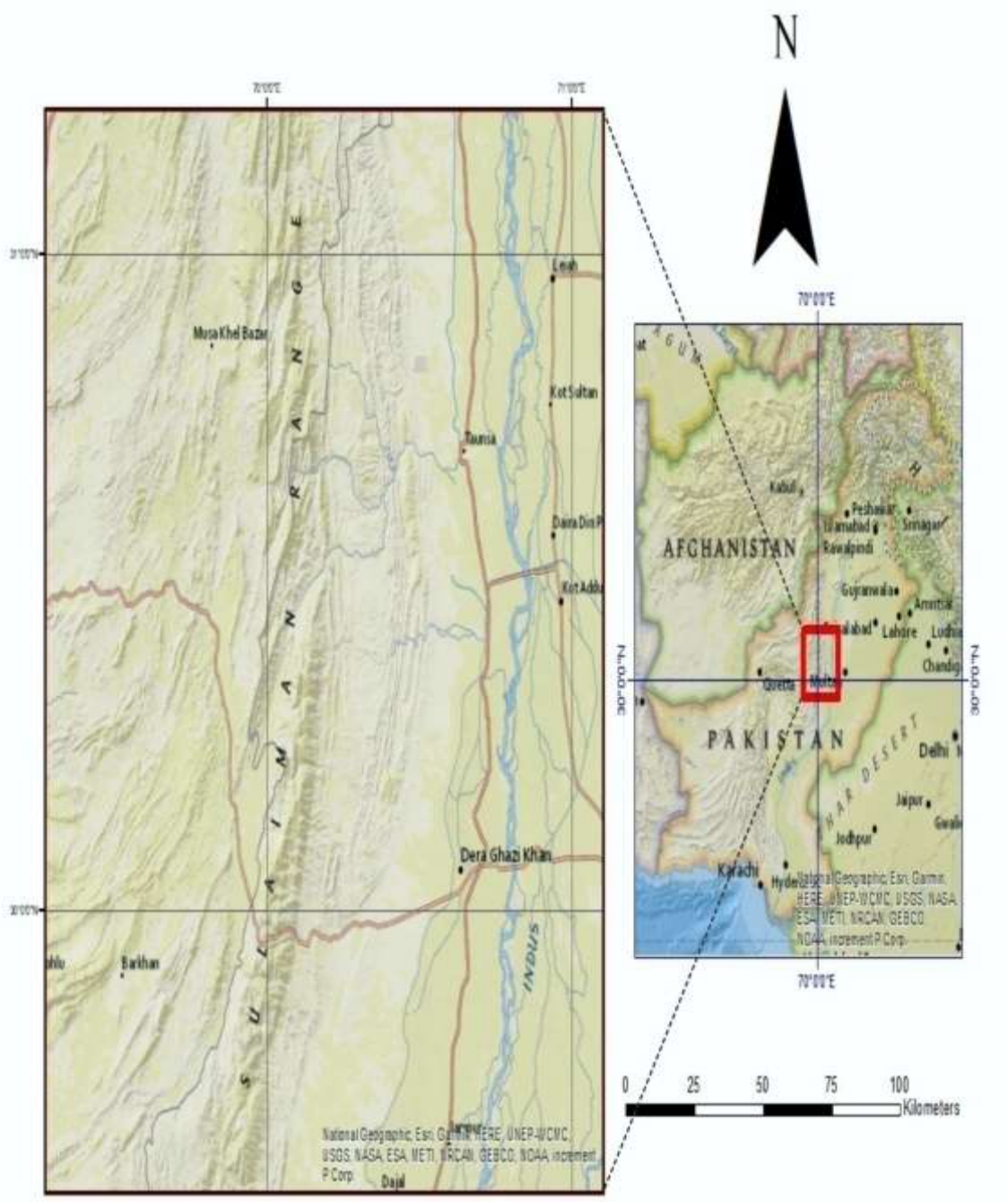

Figure 1- Google earth image shows a location map of the study area Pakistan, reused After [4].

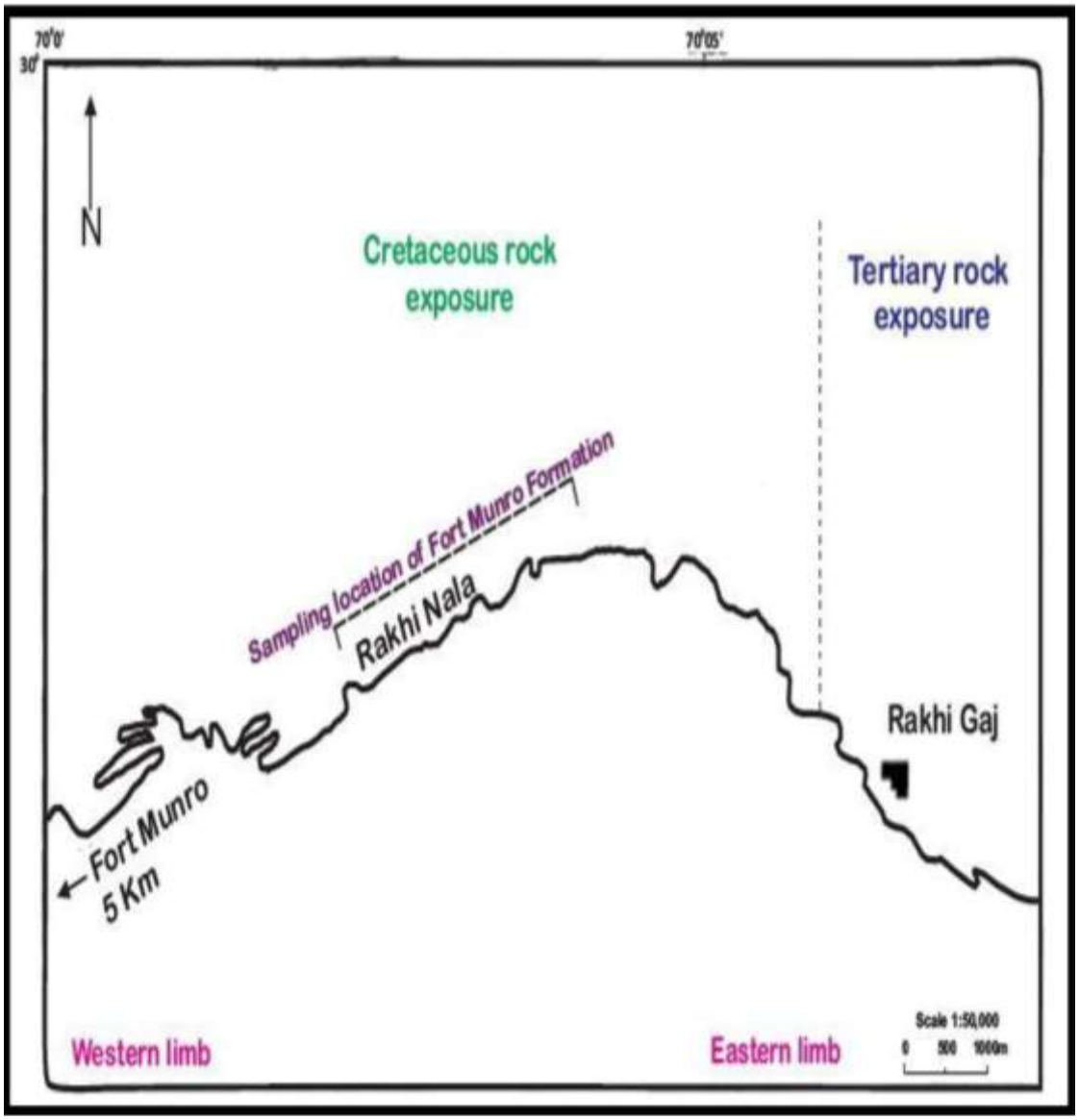

Figure 2- Route map to Fort Munro and sampling location is represented by a dotted black line.

Tectonic settings

The studied area exists within the Eastern Part of the Sulaiman Range. Sulaiman Range is a lobe-shaped, broad, and gentle thrust belt existing on the western side of the Himalayas. The Sulaiman Range has resulted from compressional stresses caused by sinistral strike-slip movement along the Chaman Fault while southward thrusting of the west boundary of the Indian plate [5]. According to Farah et al. [6], during Late Cretaceous to Paleocene, it was situated on the transitional crust of the earlier Indian passive margin that collided with the Afghan block to the west. Sulaiman Range is the widest foreland and thrust belt in the complete Himalayan mountain system. In the northwest of Kirther Range, Sulaiman Range is present with the SulaimanForedeep and Punjab Plain located in the east and Katawaz basin in the west [2] (Figure 3). It comprises approximately 10,000 m of Mesozoic to Recent strata lifted and exposed along the margins of the Sulaiman Range due to continent-continent collision [7] and [8]. Uplifting and collision have been periodic since Paleocene, but the main events of uplift and compression have happened since Pliocene [9].

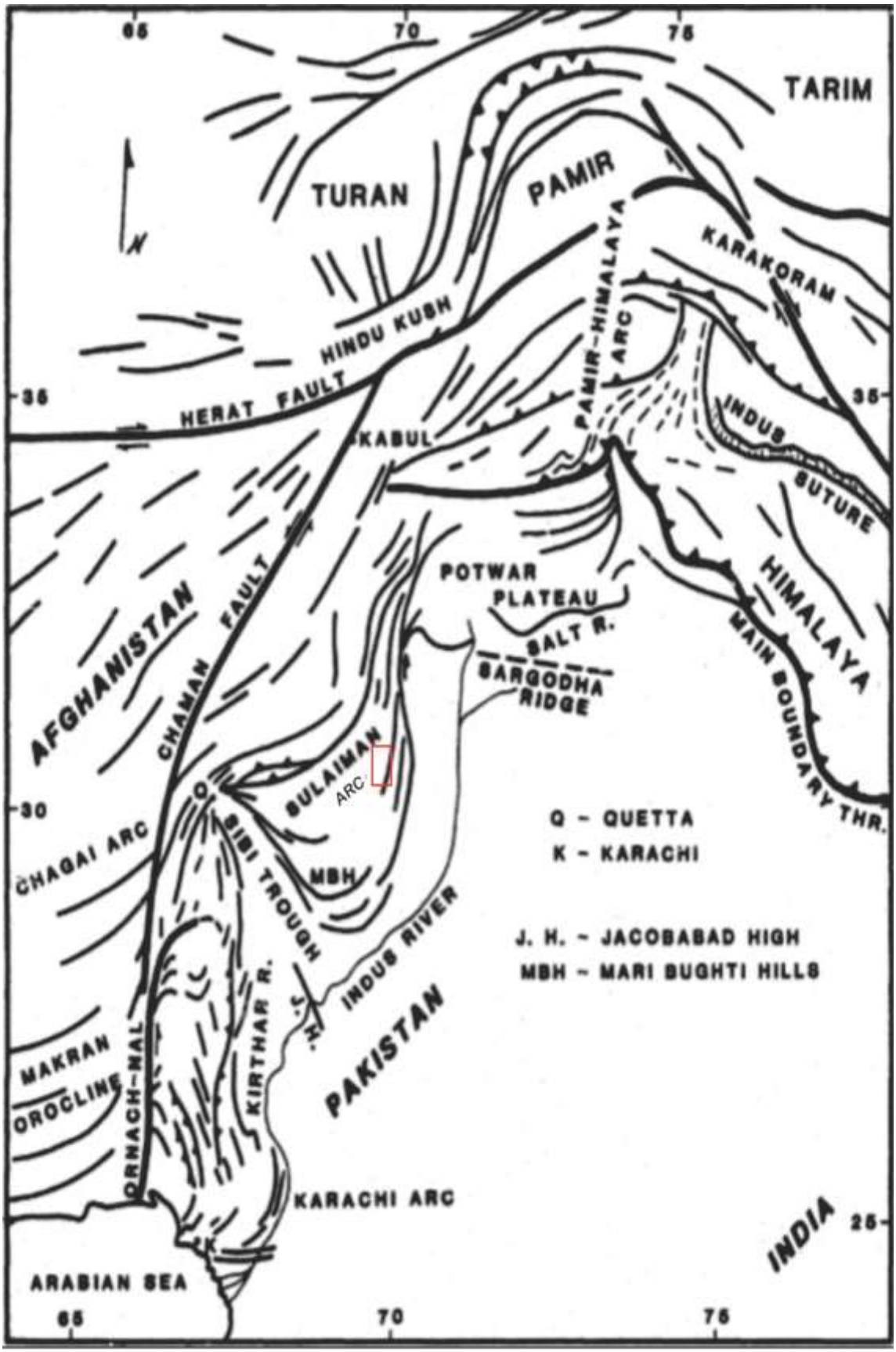

Figure 3- Tectonic map of Pakistan shows the study area's location marked in the red rectangle showing the study area [2].

Stratigraphy

The Mughalkot Formation (Upper Cretaceous) is the oldest in the study area, while the Dada conglomerate (Pleistocene) is the youngest. Fort Munro Formation has conformable lower contact with Mughalkot Formation and top beds are characterized by massive sandstone that grades into the overlying Pab Formation. According to Fatmi [10], Fort Munro Formation is comprised of limestone that is grey to black and highly compacted, thick-bedded consisting of shale and interbedded marl in the Sulaiman domain. Limestone exhibits a grey, brown to cream color, thin-bedded limestone is present in the upper part of the Formation, and massive bedded reefoidal limestone can be observed in its lower part in the Kirther domain. Fort Munro Formation has a conformable lower contact with the Mughalkot Formation throughout its exposure. Still, it has unconformable lower contact with the Parh limestone, where the Mughalkot Formation is absent in some areas. In the Sulaiman and Kirthar areas, the upper contact with Pab Formation is gradational and sharp contact with the Moro Formation. In the Quetta region (axial belt), the formation has unconformable upper contact with the Dungan Formation [3]. A generalized stratigraphic column is given in Table 1.

Table 1- Generalized stratigraphic column of the area [11].

S.No.	Age	Formation
1	Quaternary (Pleistocene)	Dada Conglomerate
2	Pliocene	Chaudwan Formation Litra Formation
3	Neogene (Mio-Pliocene)	Vihowa Formation
4	Oligo-Miocene	Chiterwata Formation
5	Eocene	**Kirthar Group** Drazinda Formation Pirkoh Limestone Domanda Formation Habib Rahi Limestone **Ghazij Group** Baska Formation Drug Formation Shaheed Ghat Formation
6	Paleogene (Palaeocene)	Dungan Formation Upper Ranikot Formation (Rakhi Gaj Formation) Middle Ranikot Formation (Khadro Formation)
		K-T Boundary
7	Cretaceous	Lower Ranikot Formation (Moro Formation) Pab Sandstone Fort Munro Formation Mughalkot Formation

Methodology

Fieldwork was done in Rakhi Gorge, Sulaiman Range. For micropaleontologic analysis, samples were collected at random intervals and based on lithologic and textural variations. The GPS was used to mark the geographic location of each sample. Thin sections were prepared and then studied under a polarizing microscope to identify different microfossils in the collected samples from the field. Twenty-six samples from top to bottom of the formation were collected, and 50 thin sections were prepared.

Observations

Fort Munro Formation is well exposed on DG khan - Fort Munro Road. The formation is conformably overlying the Mughal Kot Formation and at upper contact sandy limestone of Fort Munro Formation grades into thick-bedded sandstone of Pab Formation. The Formation is measured with Jacob's Staff, and the total thickness measured is approximately 105 (m). Lithology is observed from top to bottom. At the top, thinly bedded fine to medium-grained sandy limestone that is slightly bioturbated with a thickness of 6 m (Figure 4a), followed by 1.5 m alternate beds of limestone and shale that have thinning upward sequence. In the upper part, shale has nodules 1-5 cm in diameter and 2m of limestone fractured. Medium bedded bioturbated limestone (1m) with beds of shale at the top, 0.2 m of thinly laminated, pebbly brick-red sandstone, 3.5 m of fossiliferous and carbonaceous limestone and sandy limestone interbeds that have calcitic veins and borrows (Figure 4d), 1.5 m of carbonaceous mud (Figure 4h), 4 m massive bedded limestone with upper beds of sandy limestone having bioclasts and shell fragments (Figure 4j). Highly fractured thinly bedded calcareous mudstone (3m) with horizontal borrows, 2.5 m moderately fractured fossiliferous limestone whose top is bioturbated, 3 m of fossiliferous limestone having post-depositional vertical calcitic veins (Figure 4b), 1.5 m calcareous mudstone, 4 m of limestone and marl interbeds, 0.7 m of fossiliferous limestone and calcareous mudstone (0.5 m calcareous mudstone at the bottom, 0.2 m fossiliferous limestone at top). Fossiliferous carbonaceous limestone (2.5 m) has larger foraminiferas (Orbitoides) (Figure 4i) and 4 m carbonaceous limestone that has thinning upward sequence (Figure 4k), 11 m highly compacted limestone and mudstone with horizontal burrows (Figure 4c). Echinoderms are also abundant in it (Figure 4e and f). Fossiliferous limestone (5.5 m) has Gastropods, 7 m of moderately fractured limestone, 3.5 m of highly fractured limestone, 2.5 m of fractured mudstone with 2cm calcitic vein at the top, 4.2 m of marly limestone that has the nodular appearance. An alternate limestone of 10 m and shale (both limestone and shale have equal proportion) (Figure 4g), 5 m of thinning upward limestone sequence with bivalve fragments. Highly fractured 15 m mudstone is present at the base of the formation (Figure 4l).

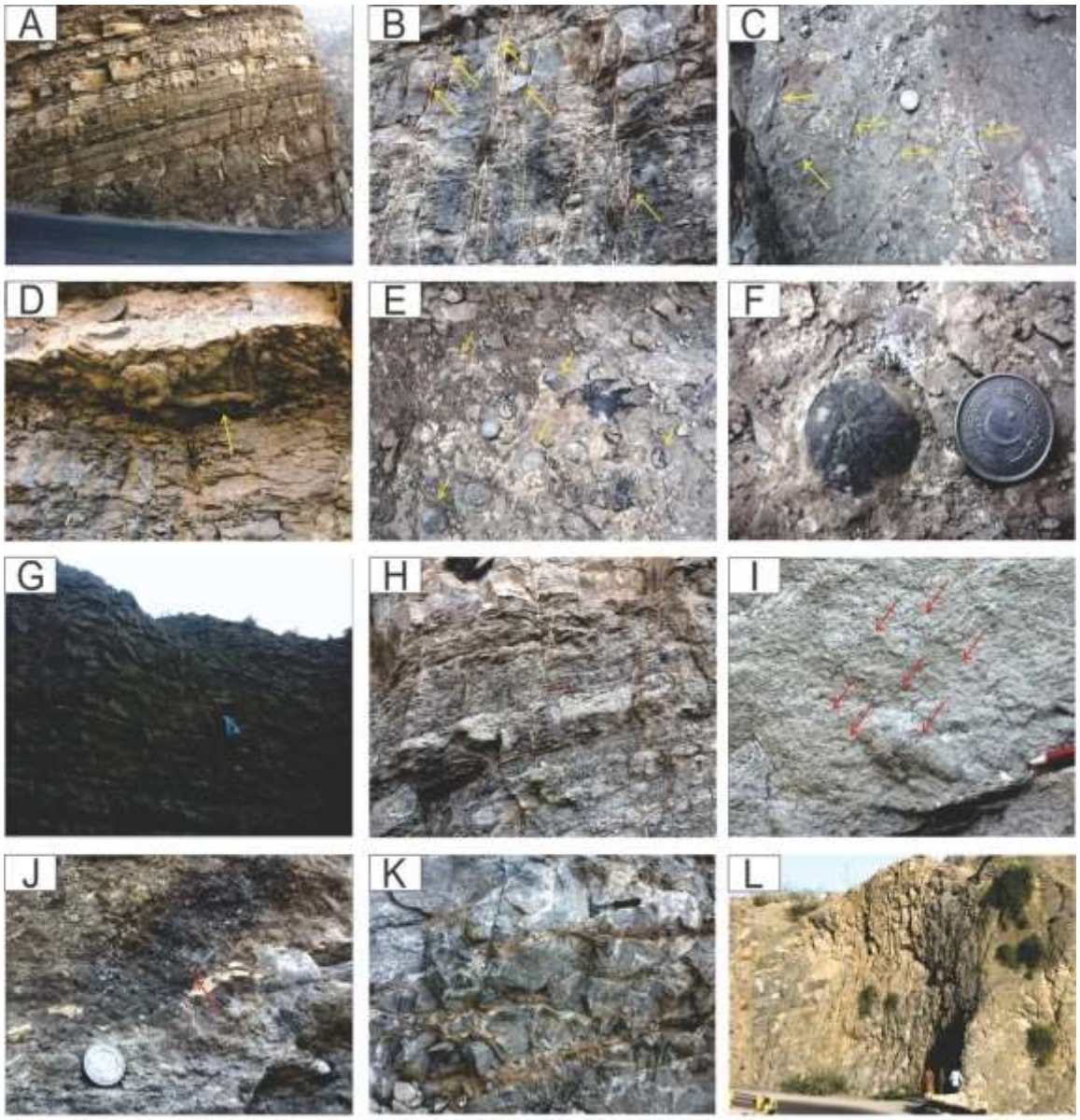

Figure 4- (A) Top thin beds of fine to medium-grained sandy limestone, (B) Fossiliferous having vertical -post-depositional veins, (C) Compacted limestone having burrows, (D) Sandy limestone having burrows, (E) Scattered Echinoderms with figure (F) showing sowing zoom-in image of an Echinoderm identified within the Formation, (G) Alternate limestone and shale, (H) Carbonaceous mud, (I) Larger Foraminifers (Orbitoides), (J) Sandy limestone with bivalves and shell fragments, (K) Carbonaceous limestone and (L) Thick sequence of mudstone at the base.

A detailed lithologic column of the Fort Munro Formation is given (Figure 5). All thin sections were analyzed carefully, and microfossils were identified, which are given below:

- *Orbitoidestissoti*Schlumberger
- *Orbitoidesapiculata*Schlumberger
- *Orbitoides media* (Archiac)
- *Orbitoideshottingeri*Van Hinte
- *Omphalocyclusmacroporus* Lamarck
- Miliolids

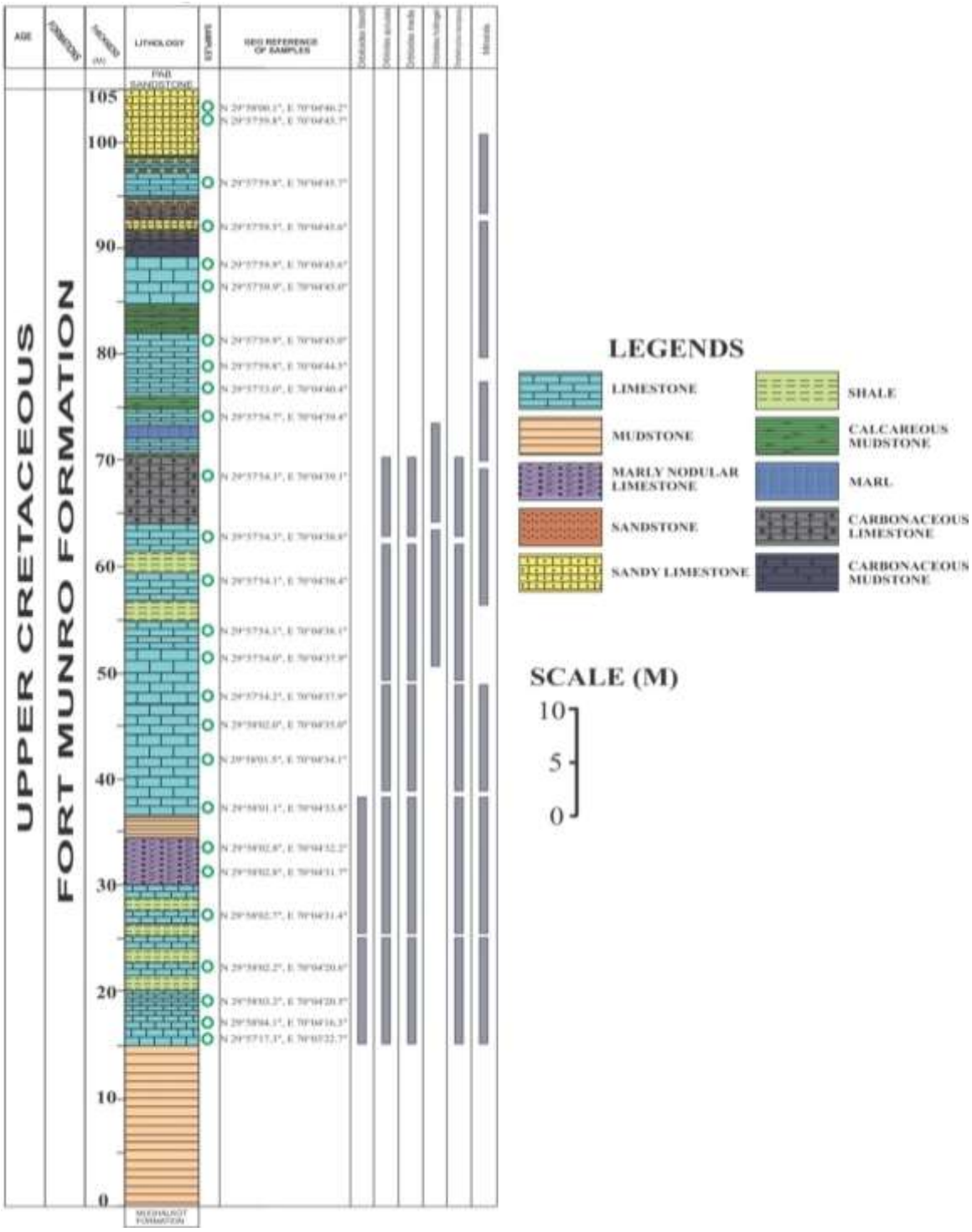

Figure 5- Detail lithologic column of the Fort Munro Formation.

Systematic Paleontology

– ***Orbitoidestissoti* Schlumberger**

Plate: 1 **Figures:** (b), (c), (d), (e), (f), (g) and(j)

Plate: 2 **Figures:** (b), (f), (g) and (h)

Plate: 3 **Figures:** (b), (c), (d) and (f)

1902 *Orbitoidestissoti* SCHLUMBERGER, p. 259, PI. 8, fig. 21-25, p. 260, fig. 3,1920 *Orbitoidestissoti* DOUVILLE, p. 214, Fig. 1, 10,1930 *Orbitoidespalmeri* GRAVELL, p. 269, pI. 22, fig. 110.

Remarks: These species were restricted to the lower part of the Fort Munro Formation. It is not present in upper and middle units.

- ***Orbitoidesapiculata*Schlumberger**

Plate: 1 **Figures:** (h)
Plate: 2 **Figures:** (f)

1901*Orbitoidesapiculata*SCHLUMBERGER, p. 465-466, pI. 8, figs. 1,4,6, pI. 9, figs. 1,4,1920 *Orbitellaapiculata* DOUVILLE, p. 216,217, fig. 49, 12, 15-18,1950 *Orbitoidesapiculata* VISSER, p. 295-296, pI. 9, fig. 4, pI. 11, figs. 1-3, 1950? *Orbitoidesbrinkae* VISSER, p. 296-297, pI. 9, fig. 5, pI. 11, figs. 2, 5.

Remarks: This species was present in both the middle and lower unit of the Fort Munro Formation but not in the upper unit.

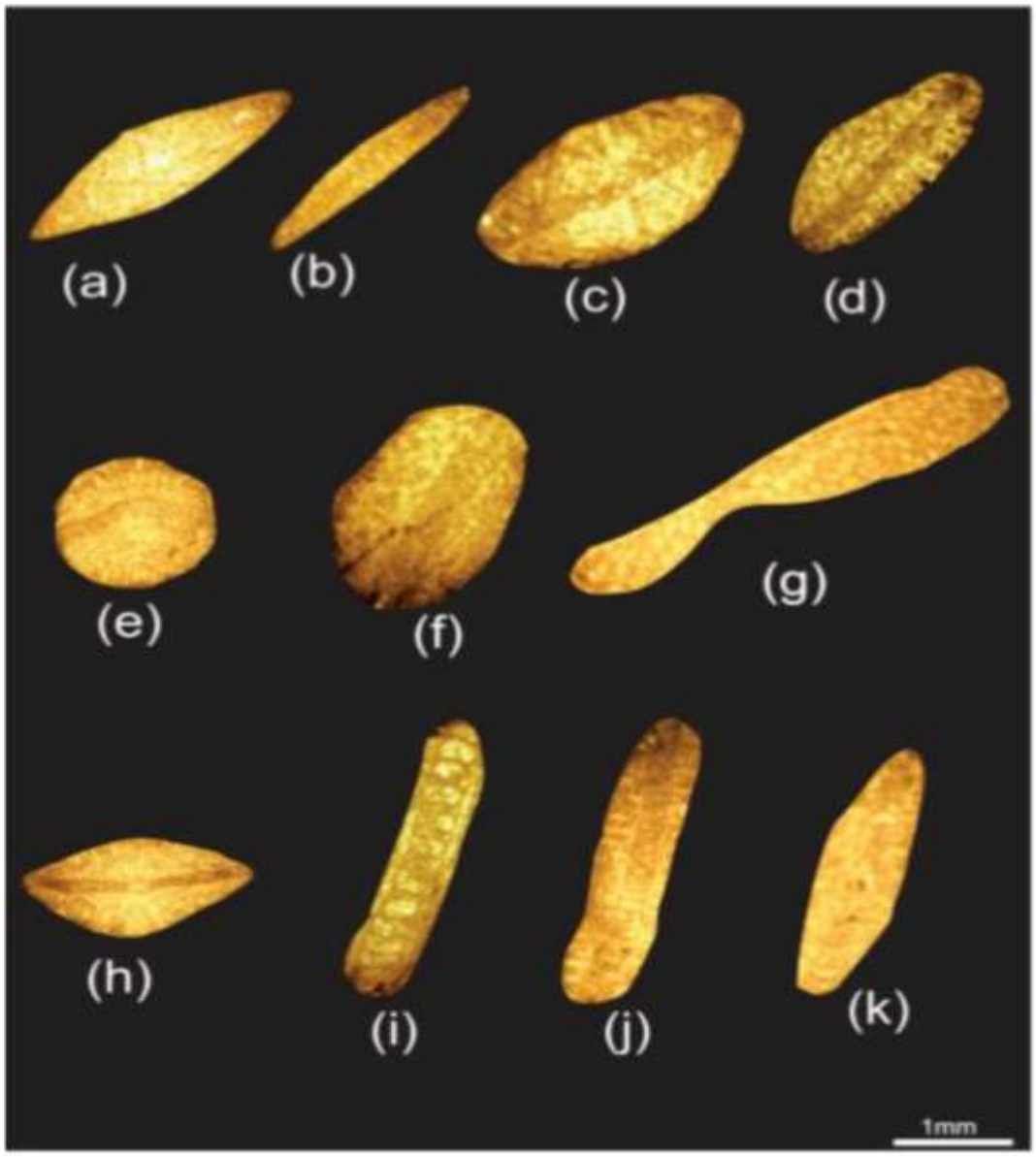

Plate 1- (a) *Orbitoides media* (Archiac), (b), (c), (d), (e), (f), (j) and (k) *Orbitoides tissoti* Schlumberger (g) *Omphalocyclus macroporas* Lamark (h) *Orbitoides apiculata* Schlumberger, (i) *Orbitoides hottingeri* Van hinte.

- ***Orbitoidesmedia* (Archiac)**

Plate: 1 **Figures:** (a)
Plate: 2 **Figures:** (e)

1837 *Orbitolitesmedia*ARCHIAC, p. 178,1849 *Orbitoidesmedia* ORBIGNY, (I.) p. 193, fig. 163,1852 *Orbitoidesmedia* ORBIGNY, (II.) p. 852, fig. 557,1901 *Orbitoidesmedia* SCHLUMBERGER, p. 464, PI. 7, Figs. 1-7,1920 *Orbitellamedia* DOUVILLE, p. 215, figs. 11, 13,1954 *Orbitoidesmedia* K. p. 73-74; PI. 1, figs. 5-7; PI. 2, Fig. 4; PI. 3, fig. 2

Remarks: This species was present in both the middle and lower unit of the Fort Munro Formation but not in the upper unit.

- ***Orbitoideshottingeri*Van Hinte**

Plate: 1 **Figures:** (i)

1927 Monolepidorbissanctae-pelagiae var. densaAstre, p. 388, pl. 20, figs. 1-12,1966 *Monolepidorbisdordoniensis* (Hofker), Hottinger p. 295, pl. 6, figs. 1-4; text figs.8a-b, e, 1966 Orbitoides*hottingeri van Hinte*, p. 338, pl.1, figs. 1-4; pl.2, figs. 5-9.

Remarks: Only one specimen of this species was identified and present in the middle unit of the Fort Munro Formation.

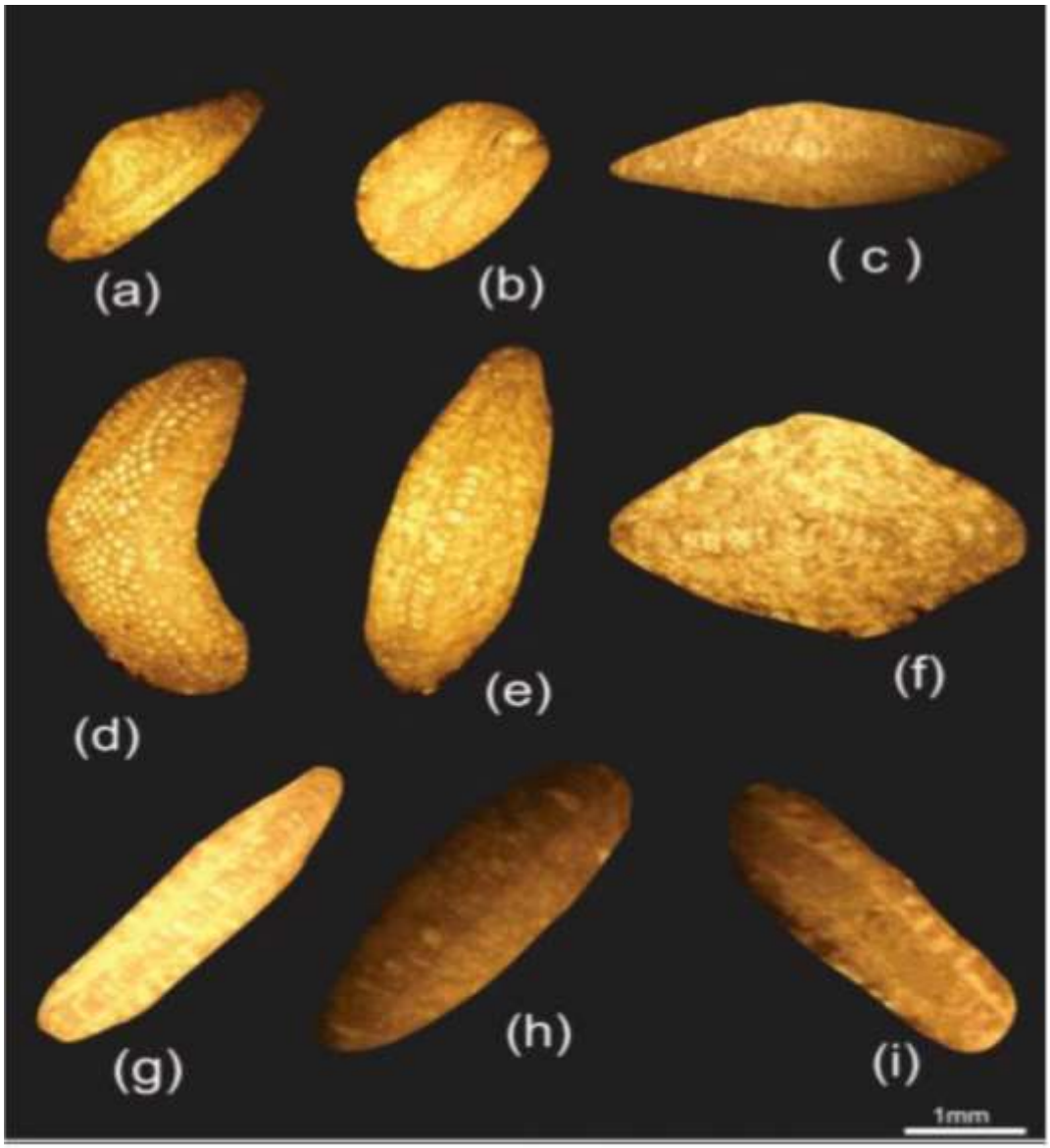

Plate 2- (a), (b), (c), (g), (h) and (i) *Orbitoides tissoti* Schlumberger, (d) *Omphalocyclus macroporas* Lamark (e) *Orbitoides media* (Archaic) (f) *Orbitoides apiculata* Schlumberger.

- ***Omphalocyclus macroporus* Lamarck**

Plate: 1 **Figures:** (g)

Plate: 2 **Figure:** (d)

1920 *Omphalocyclusmacropora* (Lamarck); Douville´, p. 230-232, pl. 8, figs. 5-14; text-figs. 3537, 1958 *Omphalocyclusmacroporus* (Lamarck); Neumann, p. 65-66, pl. 6, figs. 1-2, 4, 7; text-fig. 16, 1983 *Omphalocyclusmacroporus* (Lamarck); Jorissen, p. 255-271, fig. 1a-b, fig. 2a-b; text-figs. 3-8, 1994 *Omphalocyclus cf. macroporus* (Lamarck); O¨ zcan, p. 206-208, pl. 43, figs. 4-10; text-fig. 57.

Remarks: This species was also present in the middle and lower unit of the Fort Munro Formation.

- **Miliolids**

Plate: 3 **Figures:** (g), (h), (i), (j), (k) and(l)

Remarks: Miliolids were thoroughly distributed in all Formations but mostly occurred in the middle part of the Fort Munro Formation.

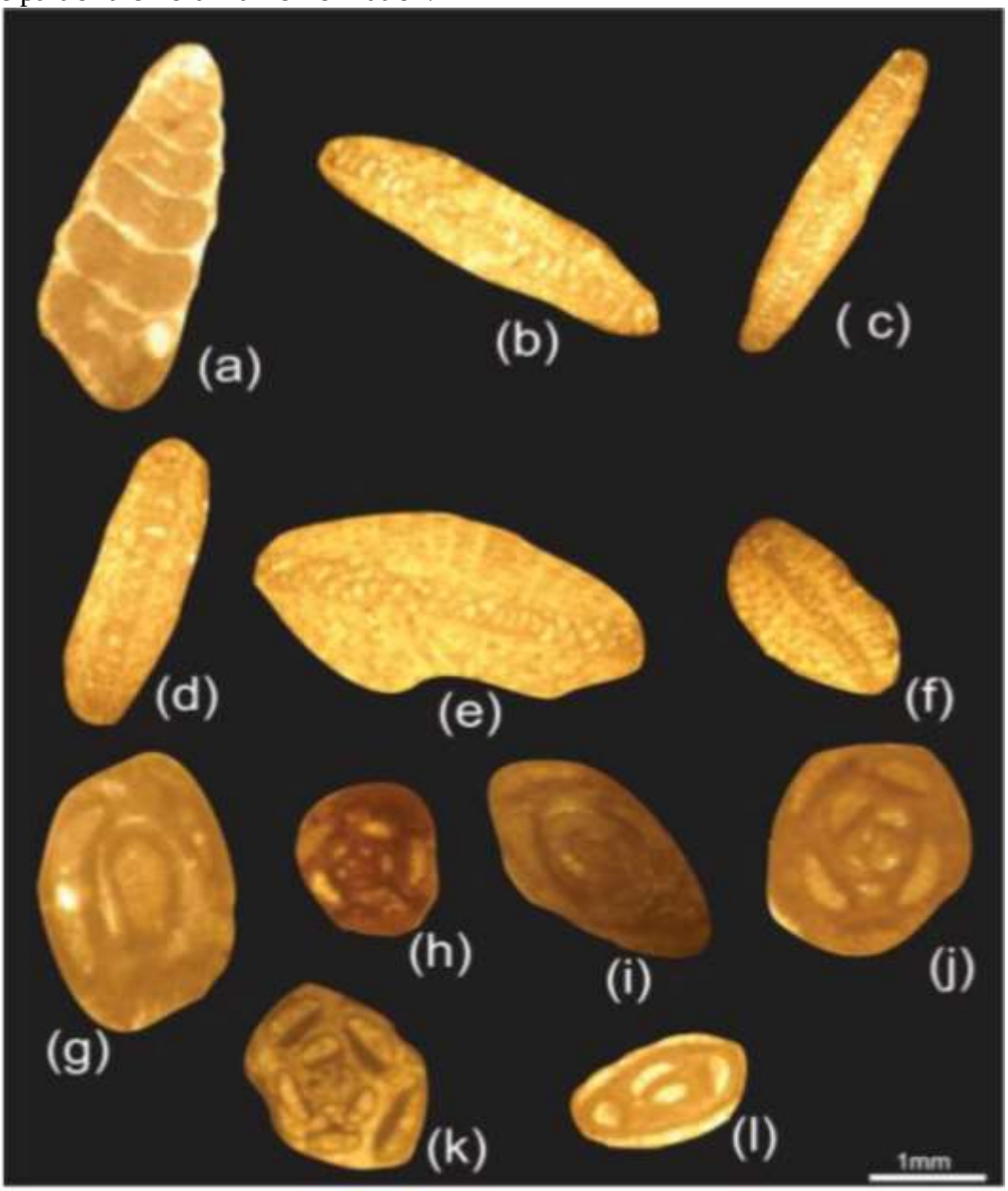

Plate 3- (a) Uniserial Foram, (b), (c), (d), (e) and (f) *Orbitoides tissoti* Schlumberger, (g), (h), (i), (j), (k) and (l) Miliolids.

Conclusion

The depositional environment identification directly links with the identification and assessment of larger benthic foraminifera and different bioclasts. Orbitoid and Miliolids are

the most common Cretaceous larger benthic foraminifera. Field evidence and petrographic assessment indicate Echinoderms, and the occurrences of restricted marine fauna like Milioloid and the shallow and open marine fauna such as Orbitoides and Bivalves significantly depict a linkage to semi-restricted inner ramp environment. The distal open-marine inner ramp to proximal middle ramp environment has been revealed from the rich Orbitoides along with the presence of the shallow marine faunas. The overall assessment derived from the field, and thin section studies the depositional environment of the Fort Munro Formation ranging from inner ramp to middle ramp.

Conflict of interest

No conflict of interest.

Reference

[1] M. D. Williams, "Stratigraphy of the Lower Indus Basin, West Pakistan," World Petroleum Cong, vol. 1, no. 19, pp. 377-390, 1959.

[2] S. S. M. I, Stratigraphy of Pakistan, vol. 12, Islamabad: Geolo. Surv. Pakistan, 1977.

[3] S. M. I. Shah, Stratigraphy of Pakistan, vol. 22, Islamabad: Geol. Surv. Pak, 2009.

[4] S. G. M. M. A. Y. A. A. N. U. S. A. Z. H. U. M. J. Khan, "Sedimentological and provenance analysis of the Cretaceous Moro formation Rakhi Gorge, Eastern Sulaiman Range, Pakistan," Iranian Journal of Earth Sciences, vol. 13, no. 4, pp. 251-265, 2021.

[5] R. S. Y. R. D. Lawrence, "Geological reconnaissance of the Chaman Fault in Pakistan," Geodynamics of Pakistan, pp. 351-357, 1979 .

[6] R. D. L. K. A. D. A. Farah, "An overview of the tectonics of Pakistan,," in Marine geology and oceanography of Arabian Sea and Coastal Pakistan, New York, Van Nostrand Reinhold Company, 1984 , pp. 161-176.

[7] H. S. Corporation, "Reconnaissance geology of part of West Pakistan," Colombo Plan Cooperative Project, Maracle Press, Toronto, 1960 .

[8] A. H. K. W. R. Hemphill, "Stratigraphy of the Bannu and Dera Ismail Khan areas, Pakistan," in USGS, New York, 1973.

[9] S. H. S. I. A. B. P. U. L. D. N. M. J. .. &. S. M. M. A. Nazeer, "Hydrocarbon potential of zinda pir anticline, eastern Sulaiman foldbelt, middle Indus Basin, Pakistan," Pakistan Journal of Hydrocarbon Research, vol. 23, pp. 73-84, 2013 .

[10] A. N. Fatmi, "Mesozoic. In Shah, S.M.I (ed.)," in Stratigraphy of Pakistan, Islamabad, Geol. Surv. Pakistan, 1977, pp. 29-56.

[11] N. A. W. A. Waheed, "Changes in palaeo currents during development of an obliquely convergent boundary (Sulaiman fold belt, southwestern Himalayas, west central, Pakistan," Sed Geol, vol. 67, pp. 237-261, 1990.