



FORAMINIFERA FROM THE LATE MIDDLE EOCENE TO EARLY MIDDLE MIOCENE SEQUENCE OF THE KACHCHH OFFSHORE BASIN, WESTERN INDIA: PALEOENVIRONMENTAL SIGNIFICANCE

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ABSTRACT

The present paper documents 7 foraminifera from the Fulra Limestone (late middle Eocene), 5 foraminifera from the Godhra Formation (early Miocene) and 13 foraminifera from the Chhasra Formation (early middle Miocene) from the Kachchh Offshore Basin. Out of 7 foraminifera discovered from the Fulra limestone, 2 foraminifera *Linderina* and *Lockhartia* broadly support the late middle Eocene age of this formation; out of 5 foraminifera recorded from the Godhra Formation, only *Miogypsina* broadly supports the Early Miocene age of this formation and out of 13 foraminifera documented from the Chhasra Formation, only 2 foraminifera, *Austrotrillina howchini* and *Pseudotaberina malaberica* precisely reinforce early middle Miocene age of this formation. Based on presence of foraminifera, it is surmised that the core samples of limestone belonging to these three formations (Fulra limestone, Godhra and Chhasra formations) were deposited in inner shelf environment with a water depth of not more than 50m in low energy condition.

Keywords: Foraminifera, Eocene, Miocene, Palaeoenvironment, Kachchh Offshore Basin, western India.

INTRODUCTION

The Kachchh Basin is the westernmost pericratonic rift basin situated at the northern end of the western seaboard of India and this basin represents the earliest rift during the break up of Africa and India (Biswas, 1992) (Fig. 1). The Kachchh Basin in onland and offshore is filled with sediments ranging in age from the middle Jurassic to Recent. In the onland part, the Mesozoic sediments are much thicker than the Cenozoic sediments present in the outer part of the basin bordering the Mesozoic uplifts and the thickness of the exposed Cenozoic sequence is 700 m while it is 5500 m in the offshore (Mishra, 2009).

The sediments of the Kachchh Offshore Basin are ranging in age from the early Cretaceous to the Recent and these sediments are divisible into eleven formations, which in order of superposition are: Bhuj Formation (middle to late Cretaceous); Mundra Formation (middle to late Cretaceous)/Naliya Formation (middle late Cretaceous); Deccan Trap (late Cretaceous); Nakhtarana Formation (late Paleocene); Jakhau Formation (early Eocene); Fulra Limestone (late middle Eocene); Tuna Formation (early Oligocene); Narayansarovar Formation (late Oligocene); Godhra Formation (early Miocene); Chhasra Formation (early middle Miocene) and Kandla Formation (middle Miocene to Recent) (Mishra, 2009) (Figure 2).

Many workers (Tewari, 1956; Tewari *et al.*, 1968; Dasgupta, 1973; Raju, 1974; Raju and Drooger, 1978; Jauhri, 1981, 1991, 1994; Saraswati, 1994, 1995; Kumar and Saraswati, 1997; Sengupta, 2009) documented large number of foraminifera from the Cenozoic of Kachchh Onshore sequence. Without illustrating foraminifera, Mehrotra (1989) delineated nine foraminiferal zones, namely *Miscellanea miscella* Partial-Range Zone and *Globorotalia pseudomenardii* Partial-Range Zone in late Paleocene; *Assilina granulosa-Nummulites mamilla* Assemblage Zone in the early Eocene; Poorly Fossiliferous Zone, *Globigerapsis kugleri- Globorotalia aragonensis* Concurrent Range Zone, *Coskinolina-Fasciolites* Assemblage

Zone, *Nummulites discorbinus-Discocyclina* Assemblage Zone in the middle Eocene; *Pellastispira madaraszii-Nummulites fabianii* Assemblage Zone in the late Eocene and *Nummulites fichteli* Range Zone in the early Oligocene from three wells of the Kachchh Offshore sequence. The present paper further records 7 foraminifera from the Fulra Limestone, 5 foraminifera from the Godhra Formation and 13 foraminifera from the Chhasra Formation from the Kachchh Offshore Sequence. The brief characteristics of these three formations are given here.

The Fulra Limestone (late middle Eocene) is named after the Fulra village and the Babia Hill near Fulra is the type locality of this formation. This formation is unconformably overlain by the Tuna Formation. It comprises cream and buff coloured massive fossiliferous limestone interspersed with clay and shale at places. The maximum thickness in offshore is 400m (Mishra, 2009). The Godhra Formation (early Miocene) occurs only offshore portion and it unconformably overlies the Chhasra Formation. It consists of grey chalky limestone, minor clay sandstone and siltstone. The maximum thickness of this formation is 1200m (Mishra, 2009). The Chhasra Formation (early middle Miocene), named after Chhasra village, is found both in Onshore and Offshore portion. This formation is unconformably overlain by the Kandla Formation. It comprises alternations of fossiliferous limestone bands and oolitic gypseous claystone/silty clay beds (Mishra, 2009).

In all, thirty six samples were collected from Regional Geosciences Laboratory, Oil and Natural Gas Corporation Ltd., Panvel, Navi Mumbai. All the foraminifera are identified in the thin sections prepared from core samples.

Fifteen limestone samples of the Fulra Limestone (late middle Eocene) were obtained from well KD-2 (Fig. 3E) (depth 1019 to 1037m). Nine limestone samples of the Godhra Formation (early Miocene) were obtained from two wells KD-1A (Fig. 3D) (depth 1600 to 1604m) and GK-17-1 (Fig. 3C) (depth 2320 to 2322m). Twelve core samples representing the

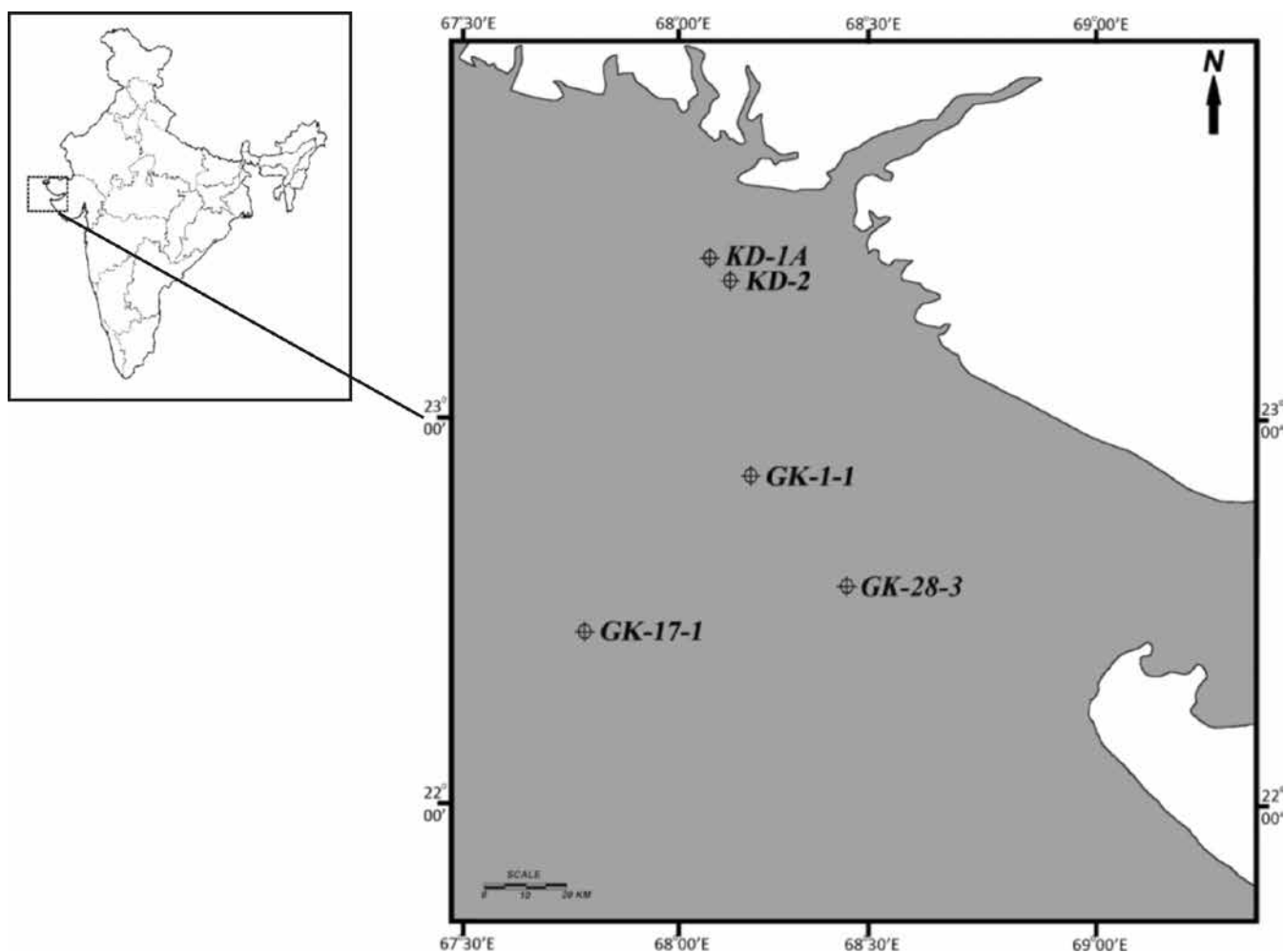


Fig. 1. Location map of the Kachchh Basin showing location of wells. (after Ravindran *et al.*, 2012).

Chhasra Formation (early middle Miocene) were obtained from GK-28-3 (Fig. 3A) (depth 736 to 745m) and GK-1-1 (Fig. 3B) (depth 1009 to 1018m).

FORAMINIFERAL ASSEMBLAGE

The Fulra Limestone (late middle Eocene) contains 7 foraminifera, namely, *Nummulites* (Pl. I, Fig. a), *Lockhartia* (Pl. I, Fig. d), *Globorotalia* (Pl. I, Fig. b), *Operculina* (Pl. I, Fig. h), *Rotalia* (Pl. I, Figs. e, g), *Textularia* (Pl. I, Fig. c) and *Linderina* (Pl. I, Fig. f) are observed in this formation. Out of these 7 foraminifera, 2 foraminifera *Linderina* and *Lockhartia* broadly support the late middle Eocene age of the Fulra Limestone (Table 1).

The Godhra Formation (early Miocene) has presence of 4 foraminifera, viz. *Ammonia* (Pl. I, Figs. i, j), *Operculina* (Pl. I, Fig. k), *Miogypsina* (Pl. I, Fig. n), *Textularia* (Pl. I, Fig. m) and one unidentified agglutinated foraminifer (Pl. I, Fig. l). Out of these 5 foraminifera *Miogypsina* broadly supports the early

Miocene age of the Godhra Formation (Table 1).

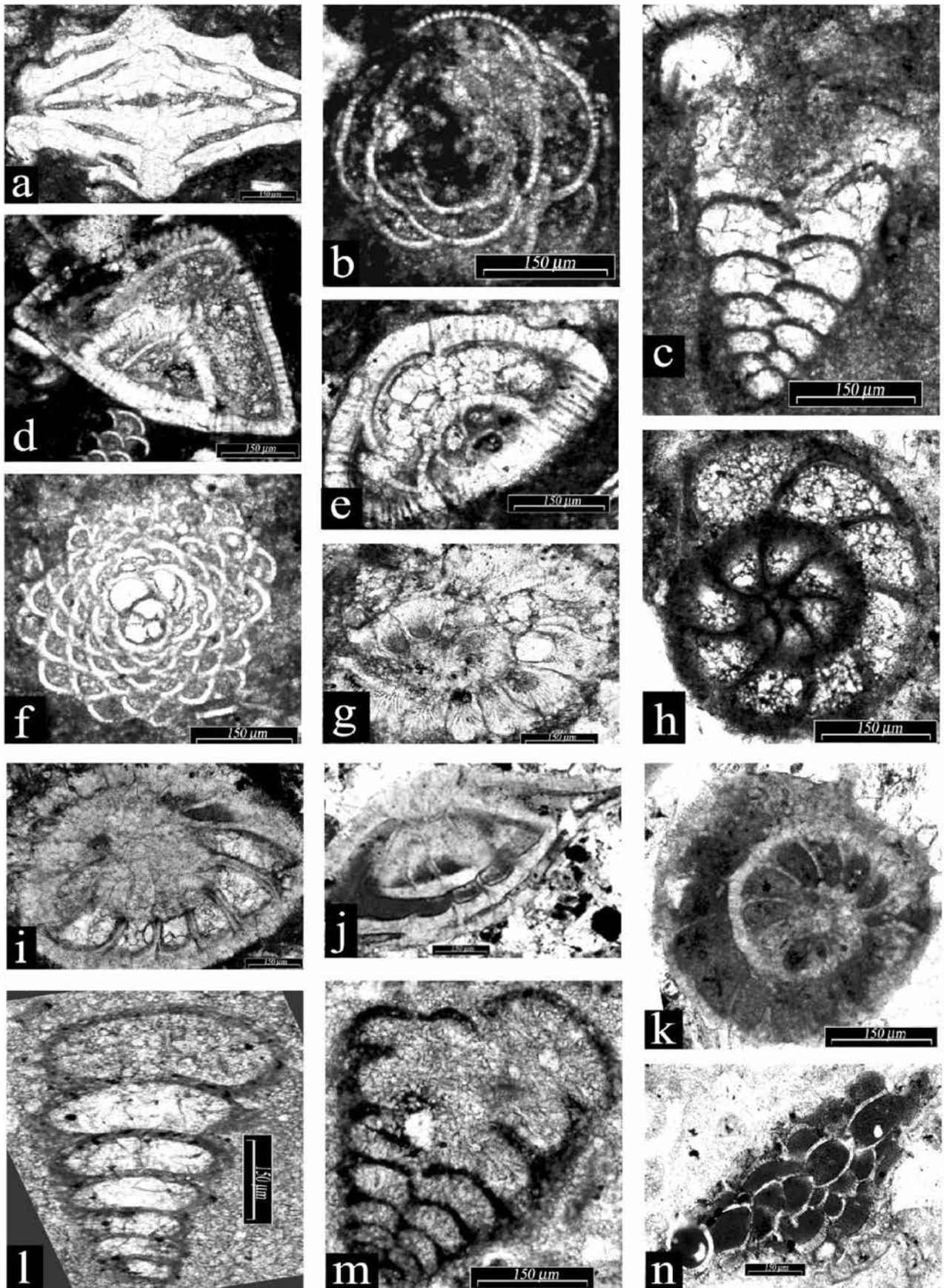
The Chhasra Formation (early middle Miocene) contains 13 foraminifera, namely *Textularia* (Pl. II, Fig. j), *Globorotalia* (Pl. II, Fig. i), *Sphaerogypsina* (Pl. II, Fig. g), *Operculina* (Pl. II, Fig. l), *Planolinderina* (Pl. II, Fig. d), *Spiroloculina* (Pl. II, Fig. a), *Miogypsina* (Pl. II, Fig. f), *Biloculina* (Pl. II, Fig. k), including 3 foraminiferal species viz., *Austrorillina howchini* (Pl. II, Fig. b), *Pseudotaberina malaberica* (Pl. II, Fig. m), *Sorites orbicularis* (Pl. II, Fig. e), Miliolids (Pl. II, Fig. c), Rotalids (Pl. II, Fig. h) Out of 13 foraminifera, only 2 *Austrorillina howchini* and *Pseudotaberina malaberica* precisely reinforce early middle Miocene age of the Chhasra Formation (Table 1).

PALEOENVIRONMENTAL SIGNIFICANCE

Larger foraminifera have been common in the shallow marine shelf carbonates formed in warm water environments since the Late Palaeozoic. Extensive Cretaceous and Cenozoic shelf carbonates were produced by large benthic foraminifera.

PLATE I

a to h: Foraminifera from Late Middle Eocene Fulra Limestone: a: *Nummulites* (Sample No. S4). b: *Globorotalia* (Sample No. S4). c: *Textularia* (Sample No. S4). d: *Lockhartia* (Sample No. S4). e: *Rotalia* (Sample No. S5). f: *Linderina* (Sample No. S4). g: *Rotalia* (Sample No. S4). h: *Operculina* (Sample No. S4). i to n: Foraminifera from Early Miocene Godhra Formation: i: *Ammonia* (Sample No. C12). j: *Ammonia* (Sample No. C13). k: *Operculina* (Sample No. C14). l: Agglutinated foraminifer (Sample No. G1). m: *Textularia* (Sample No. G6). n: *Miogypsina* (Sample No. G2).



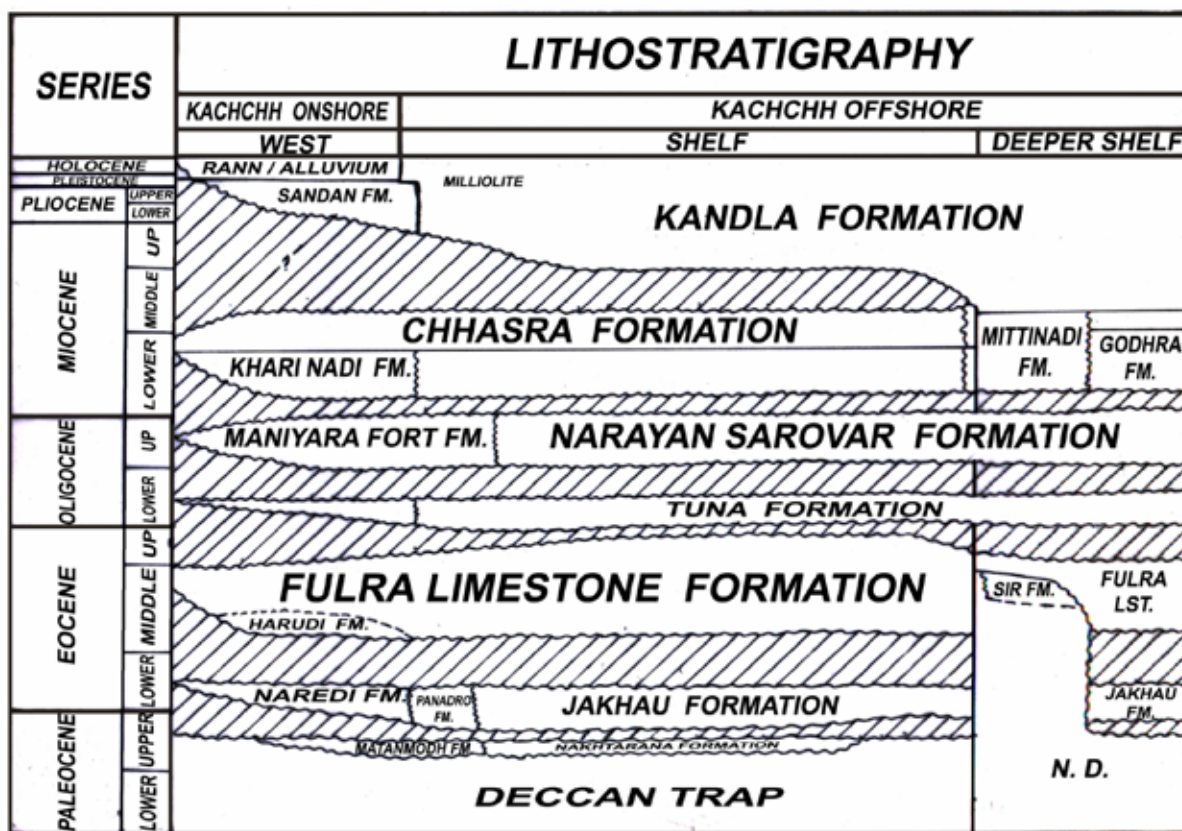


Fig. 2. Lithostratigraphy of the Kachchh Basin.

Larger foraminifera contribute significantly to the formation of sand-sized carbonate sediments in reefs and other shallow carbonate environments due to the high turnover rates of the population (Hallock, 1981). Benthic larger foraminifera with green and red algal symbionts are restricted to shallow euphotic areas. Differences in light attenuation by the water column are reflected by different wall structures (Hohenegger, 1999). Planktic foraminifera with algal endosymbionts occur in water depths down to 50 and 100 m. The abundance of foraminifera supports warm water shelf environment (Rey *et al.*, 1993). The modern assemblage of *Ammonia*, *Austrorillina*, and *Spiroloculina* occur in inner shelf conditions with a water depth of not more than 50m, while *Miogyopsina* is a eurytopic form inhabiting lagoon to shallow subtidal environment and low to high energy conditions (Kumar and Saraswati, 1997). Kathal (2012) stated that species of *Textularia* live in cold warm water (0-500m) in the shelf to bathyal region; *Ammonia* occurs in inner shelf; *Globorotalia* species inhabit inner shelf to bathyal region; Miliolids occurs at depths of 0-100m and *Nummulites* at depth up to 200m. Reiss and Hottinger (1984) pointed out that the *Operculina* species occur in low energy and medium light within the lagoon-shelf region. In general, larger benthic foraminifera occur in warm waters in the photic zone. *Nummulites* occurs in the shallower, inner ramp/shelf settings.

The Fulra Limestone shows presence of 7 foraminifera.

Presence of *Nummulites* suggests shallower, inner ramp/shelf settings (Boukhary *et al.*, 2005; Adabi *et al.*, 2008) and *Operculina* is indicative of low-energy conditions (Reiss and Hottinger, 1984). Therefore, it is surmised that the core samples of the Fulra Limestone were deposited in inner-shelf environment with water depths not more than 50m with low energy. The Godhra Formation is characterized by 5 foraminifera. Presence of *Ammonia* indicates inner-shelf environment with depth not more than 50m (Reiss and Hottinger, 1984; Kumar and Saraswati, 1997). Hence, it is concluded that the core samples of the Godhra Formation were deposited in the shelf region with depth of not more than 50m under low-energy conditions. The Chhasra Formation shows presence of 13 foraminifera. *Austrorillina* and *Spiroloculina* occur in inner-shelf conditions with a water depth of not more than 50m (Kumar and Saraswati, 1997) and *Operculina* is found in low-energy conditions (Reiss and Hottinger, 1984). Therefore, it is surmised that the core samples of the limestone of the Chhasra Formation were deposited in low-energy, inner-shelf environment with a water depth of not more than 50m.

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PLATE II

Foraminifera from the early middle Miocene Chhasra Formation a: *Spiroloculina* (Sample No. C1). b: *Austrorillina howchini* (Sample No. C2). c: Miliolid (Sample No. C2). d: *Planolinderina* (Sample No. C1). e: *Sorites orbicularis* (Sample No. C3). f: *Miogyopsina* (Sample No. C3). g: *Sphaerogypsina* (Sample No. C2) h: Rotaliid (Sample No. C10). i: *Globorotalia* (Sample No. C2). j: *Textularia* (Sample No. C1). k: *Biloculina* (Sample No. C10). l: *Operculina* (Sample No. C3). m: *Pseudotaberina malabarica* (Sample No. C2).

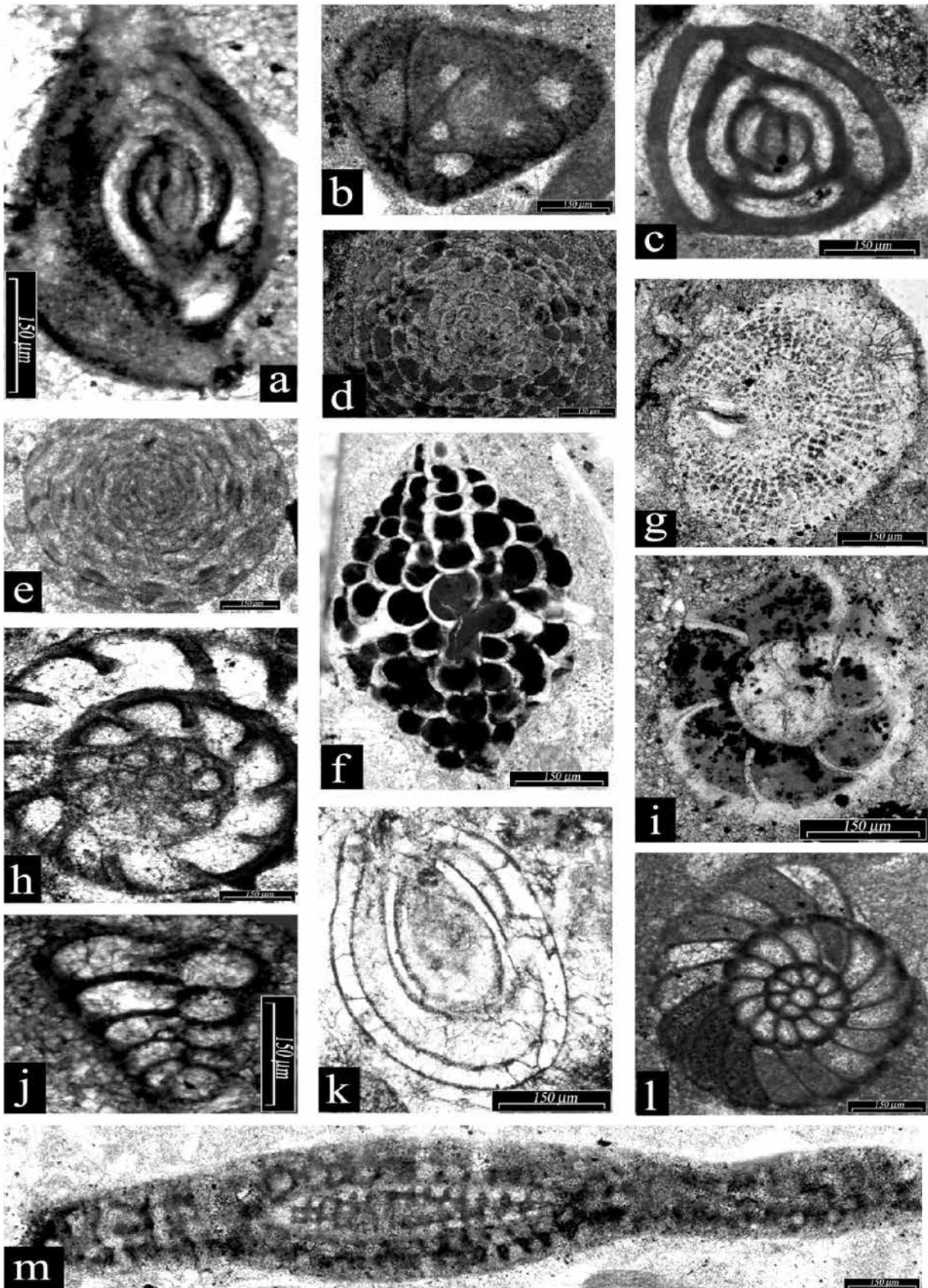


Table 1: Stratigraphic ranges and formation-wise distribution of the Foraminifera recorded from late middle Eocene to Early Middle Miocene Kachhh Offshore (After Loeblich and Tappan, 1964, 1988; Kathal, 2012).

Sr. No.	Name of Foraminifera	Stratigraphic range	Formation		
			Fulra Limestone (Late Middle Eocene)	Godhra (Early Miocene)	Chhasra (Early Middle Miocene)
1.	<i>Ammonia</i>	Pliocene to Recent	A	P	A
2.	<i>Austrorillina howchini</i>	Early Miocene	A	A	P
3.	<i>Biloculina (=Pyrgo)</i>	Late Eocene to Holocene	A	A	P
4.	<i>Globorotalia</i>	Paleocene to Recent	P	A	P
5.	<i>Linderina</i>	Eocene to Miocene	P	A	A
6.	<i>Lockhartia</i>	Paleocene to Middle Eocene	P	A	A
7.	<i>Miogypsina</i>	Late Oligocene to Early Miocene	A	P	P
8.	<i>Nummulites</i>	Paleocene	P	A	A
9.	<i>Operculina</i>	Eocene to Recent	P	P	P
10.	<i>Planolinderina</i>	Late Oligocene to Late Miocene	A	A	P
11.	<i>Pseudotaberina malaberica</i>	Early to Middle Miocene	A	A	P
12.	<i>Quinqueloculina</i>	Jurassic to Recent	A	A	P
13.	<i>Rotalia</i>	Late Cretaceous to Recent	P	A	A
14.	<i>Sorites orbicularis</i>	Miocene to Recent	A	A	P
15.	<i>Sphaerogypsina</i>	Eocene to Recent	A	A	P
16.	<i>Spiroloculina</i>	Late Cretaceous to Recent	A	A	P
17.	<i>Textularia</i>	Pennsylvanian to Recent	P	P	P

*P-Present and A-Absent

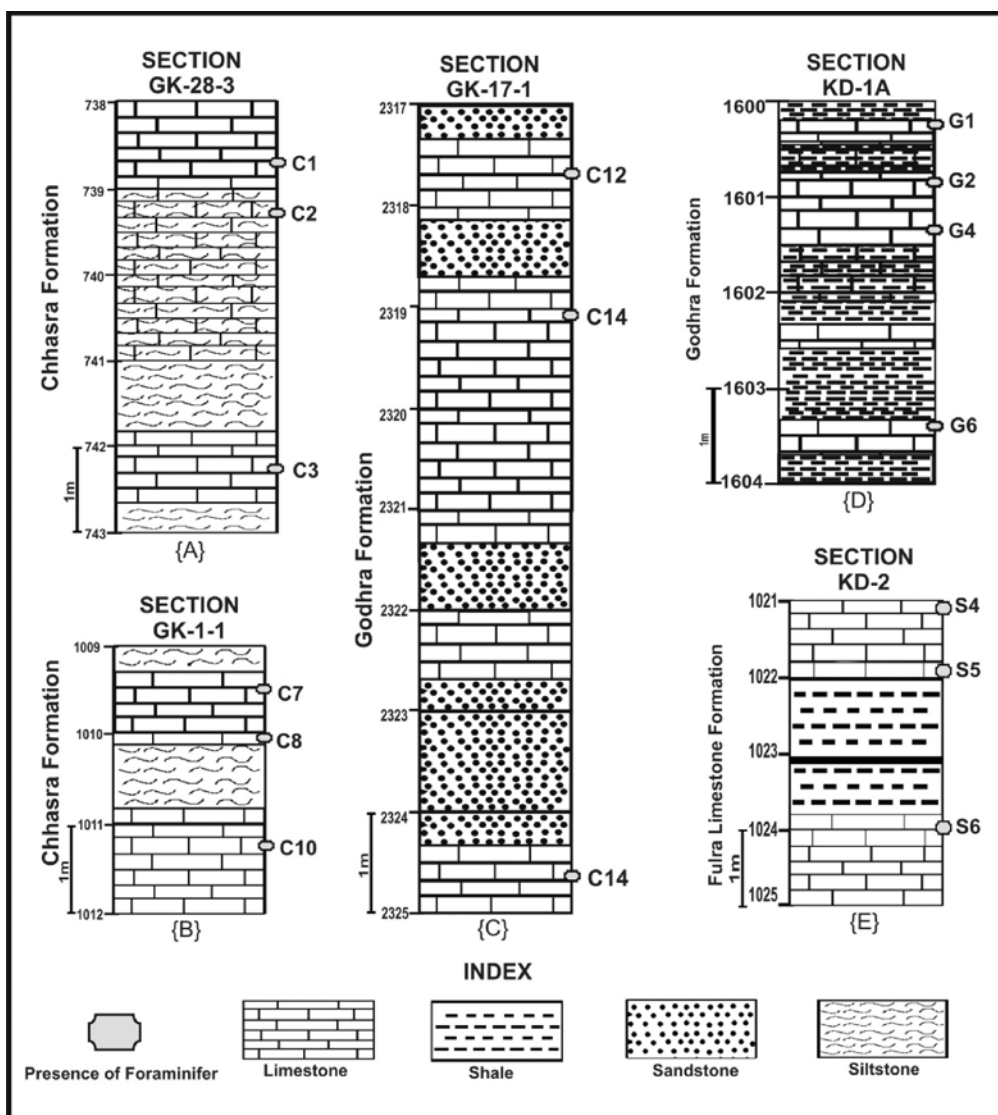


Fig. 3. Lithosections showing position of samples yielding foraminifera.

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