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A SYNTHESIS OF FORAMINIFERAL RESEARCHES ON JURASSIC SEDIMENTS OF KUTCH BASIN, INDIA

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ABSTRACT

This paper presents a synthesis of the reasearch work carried out so far on foraminifera of the Jurassic rocks of Kutch, western India. An overview of the literature reveals that so far all Jurassic dome-shaped outcrops, except one, exposed in the Kutch Mainland and one 'island' in the Northern Island Belt have been investigated for their foraminiferal content. A total of 57 papers have been published besides two unpublished theses.

The present overview reveals that a total of 507 foraminiferal species belonging to 88 genera have been described so far. The gross foraminiferal composition of Kutch Jurassics include 347 known species recorded from other Jurassic localities of the world, 41 new species, and 119 indeterminate species. Vaginulinids and nodosariids dominate the foraminiferal assemblages throughout the different outcrops of Kutch Jurassic. Both agglutinated and calcareous forms are present in Kutch having an average ratio of about 1:2.67 but it is higher (1:3.88) in Habo Dome. Most foraminiferal assemblages were found to confine within the sediments of Patcham and Chari formations. A few well-known Jurassic species occur in nearly all the assemblages. Epistominids, the most important group of Jurassic benthic foraminifera comprising both reticulate and non-reticulate forms are abundant. Jurassic nodosariids and vaginulinids recovered from Kutch material exhibit a high degree of inter- as well as intra-specific variation creating confusion in their systematics.

Nearly all the foraminiferal assemblages of Kutch suggest that the Patcham and Chari formations accumulated in an open marine environment of mid to outer shelf region having normal salinity and well-oxygenated water.

During Middle and Late Jurassic times, the Kutch region had a sea connection with Rajasthan, Afghanistan, Iran, Egypt, Somalia and Madagascar when these regions were also covered by a southwestern arm of the Tethys, the Indo-East African Gulf which was located at the border of the Tethyan and Antiboreal realms.

However, more investigations on foraminifera covering these aspects as well other interpretations such as palaeoclimate, employing detailed statistical and isotopic analyses are required for a thorough understanding of the famous Jurassic rocks of Kutch.

Keywords: Synthesis, Foraminiferal studies, Kutch, Systematics, Biostratigraphy, Palaeoenvironment, Palaeogeography.

INTRODUCTION

Marine Jurassic sequence is mainly exposed in the Kutch Mainland region of Gujarat state, western India, known for its fossil treasures. This region has been a favorite megafossil locality for palaeontologists in the past and the present. Kutch sedimentary basin is a peri-continental basin in the extreme west of Indian Peninsula covering an area of 26,400 Km^2 with an outcrop area of 8000 Km^2. The Mesozoic sediments are 2430 meter thick and fill the major part of the basin (Fig. 1) (Pandey *et al*., 2009) whereas 600 meter thick Palaeogene sediments are deposited in the outer parts, bordering the Mesozoic uplifts. The Kutch basin displays an excellent development of Jurassic rocks ranging in age from Bajocian to Tithonian (Biswas, 1993; Fürsich *et al*., 1994, 2001; Krishna *et al*., 2000; Krishna, 2005, 2012; Rai., 2003; Rai and Jain, 2012). Although considerable research has been carried out on the ammonites and other megafossils of these rocks, relatively little attention has been paid to their microfossils including benthic foraminifera and the first detailed attempt in this regard was made by Subbotina *et al*., (1960) and later various researchers carried out detailed work on the taxonomy, biostratigraphy, depositional environment and palaeogeography of the Kutch Jurassics on the basis of foraminifera recovered from various areas. The present work deals with the synthesis of the past researches carried out on foraminifera in different areas of the Kutch Basin.

Most of the foraminiferal studies on Kutch Jurassics deal with the systematics and taxonomy with little emphasis on biostratigraphic, paleoecological and paleogeographic interpretations. These studies suggest that microfossils, especially the foraminifera are abundant and excellently preserved in these rocks and need detailed studies and for this a compilation and review of the previous studies are vital.

The Kutch Basin falls under Identified Prospectivity Category (IPC) basins of India and offers a great potential for future hydrocarbon resource of the country. Keeping these facts in view, a synthesis of the foraminiferal studies of the following previously reported areas of the Jurassic rocks of the Kutch Basin is presented in this paper: Habo Hills, and Khawda Nala section, Pachchham Island (Subbotina *et al*., 1960); Kalajar Nala Section, Habo Hills (Bhalla and Abbas, 1978); Badi village, Jhurio Hills (Bhalla and Talib, 1980); Kaiya Hills (Bhalla and Lal, 1985); Jumara Hills (Bhalla and Gaur, 1987); Jhurio Hill (Mandwal and Singh 1989); Sonwa Nala section, Jhurio Hill (Bhalla and Talib 1991); Khawda Nala section, Pachchham Island; Jhurio Dome; Jumara Dome and Habo Dome (Pandey and Dave, 1993); Keera hills (Gaur and Sisodia 2000); Nara Dome (Gaur and Singh 2000); Jumara Dome (Gaur and Talib 2009); Ler Dome (Talib and Faisal 2006); Kaiya Dome (Talib *et al*., 2012a; Talib *et al*., 2017c); Keera Dome (Talib *et al*., 2012b); Kachchh Basin; Jara,

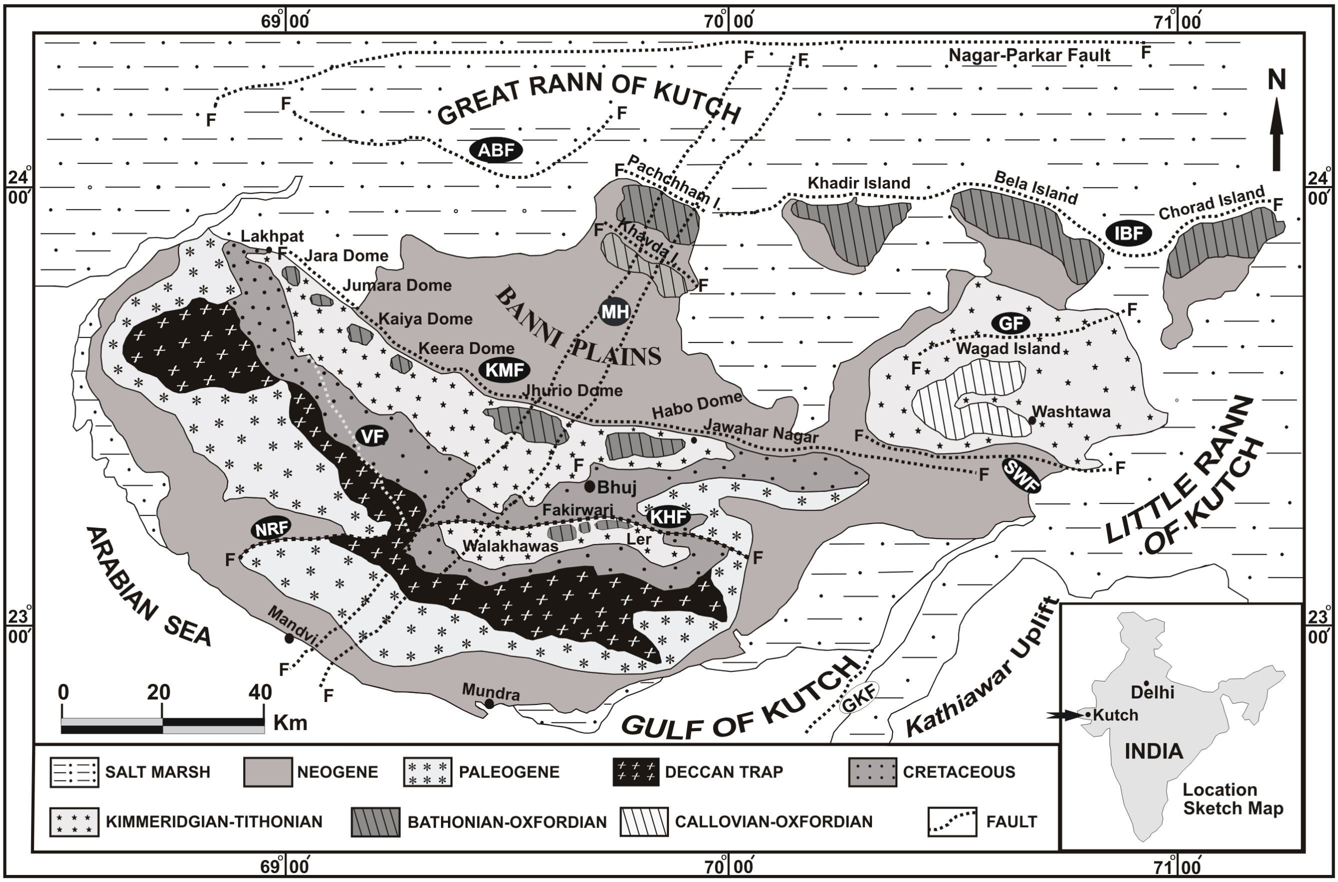

Fig 1. Schematic geological map of Kutch with important Jurassic outcrops and major structural features (after Biswas & Khattri, 2002; Pandey *et al*., 2009) (MH: Median High, KMF: Kutch Mainland Fault, ABF: AllahBund Fault, KHF: Katrol Hill Fault, VF: Vigodi Fault, IBF: Island Belt Fault, NRF: Naira River Fault, SWF: South Wagad Fault, GF: Gedi Fault and GKF: Gulf of Kutch Fault).

Jhurio and Jumara domes (Al-hussein, 2014); Black Limestone Member, Habo Formation, Habo Dome (Talib *et al*., 2016); Dharang Member, Habo Dome (Talib *et al*., 2017a); Fakirwadi Dome (Bhat *et al*., 2016); Jara Dome (Tirvedi, 2004; Wasim *et al*., 2017); Gorandongar, Patcham 'Island' (Varshney, 2006) (Fig. 1).

The main objectives of the present paper are:

1. To prepare a bibliography of the Jurassic foraminiferal studies in Kutch Basin.
2. To highlight the major contributions of different published and unpublished studies.
3. To identify the grey areas and highlight the thrust areas with regard to the foraminiferal studies.
4. To present a synthesis of the studies employing foraminifera for interpreting biostratigraphy, palaeoenvironment, and palaeogeography of the Kutch Basin during Jurassic times.

GEOLOGICAL SET-UP OF THE KUTCH BASIN

Jurassic rocks show a wide aeral extent in the Kutch region and deposited on the Precambrian basement with an unconformity (Bardhan and Dutta, 1987; Biswas, 1993; Mitra *et al*., 1979). These rocks were formed in a small sedimentary basin situated at the eastern margin of a southern extension of the Neotethys, the Malagassy Gulf, at a palaeo-latitude of 38^0S during the Middle to Late Jurassic (Dercourt *et al*., 2000) (Fig. 1). Jurassic rocks of Kutch are exposed in three east-west trending anticlinal ridges (Biswas, 1991), the middle ridge with a length of 193 km is the most prominent and included in the Kutch Mainland. It is broken up into a number of domed outcrops from West to East, *viz*., Jara, Jumara, Nara, Keera, Jhurio, Habo, Ler, and Fakirwadi having quaquaversal dips (beds dipping in all direction away from the centre). The dome shaped outcrops of the Jurassic rocks in this region might be due to igneous activity related to Deccan volcanism (Tewari, 1948). The original lithostratigraphic classification of the Jurassic rocks of Kutch proposed by Waagen (1875) is still being followed with some modifications in the rank of lithostratigraphic units as defined in the 'Code of Stratigraphic Nomenclature of India' which divides these rocks into Patcham, Chari, Katrol and Umia formations in ascending order, ranging in age from Bajocian to Tithonian.

REVIEW OF THE PAST WORK ON JURASSIC FORAMINIFERA OF KUTCH

General Considerations

The Kutch Basin of Gujarat State has outrivelled all the Jurassic sites of the so-called Tethyan Realm. The marine Jurassic sequences are developed extensively in three parts of the Kutch region, *viz,* the Kutch Mainland or Central Kutch, four 'Islands' in the northern part of the Basin, and an isolated outcrop in the eastern Kutch near Wagad. The Kutch Mesozoics, ranging in age from Late Bajocian to Tithonian are renowned all over the world for their plentiful and varied megafauna, especially the ammonoides which contributed in solving problems related to framing of startigraphic sequence and its correlation with the standard European stages, fixation of age, and to some extent palaeoecology and palaeozoogeography. Regarding Kutch, the citation of Arkell (1956) is very true; "Kutch is probably the most favoured locality in the world for upper Jurassic Ammonites by the reasons of great abundance and variety, good preservation, and ideal exposures."

Among early researchers, although of historical importance only, Grant (1837) and Blandford (1867) were the contributors worth mentioning. The first capacious and systemtic accounts on mapping and geology of Kutch was presented by Wynne (1872) which became the basis for all the subsequent studies carried out in the region till date.

An epitome of published literature on Kutch Jurassic evinces that most researches of the Indian as well as foreign biostratigraphers and palaeontologists were focused mainly on the ammonoids obtained from these rocks. However, the study on foraminifera from Jurassic sediments of Kutch came into light for the first time in 1957 (Tewari, 1957). At present, there is a long list of publications on various geological aspects of Kutch region including Sedimentology, Palaeontology, Micropalaeontology, Biostratigraphy and Seismology. It is neither possible nor desirable to deal with all the earlier researches on different problems of geology of this region as it is beyond the scope of the present study. Therefore, investigations concerning only foraminifera have been dealt in the present study.

Jurassic Foraminiferal Studies on Kutch Basin

Tewari (1957 *in* S.R.N. Rao) not only recorded molluscs from Habo Hills, exposing rocks ranging from Bathionian to Argovian, but also foraminifera for the first time which included *Aulotortus, Textularia*, *Bigenerina*, *Spiroplectammina* and *Gaudryina*.

The first detailed study of the Jurassic foraminifera of Kutch was carried out by Subbotina *et al*. (1960) who described and illustrated prolific assemblages from southeast of Lodai Village, on the eastern flank of Habo Hills and from shales of Khavda. Out of 34 Species, 13 were new, viz., *Lenticulina dilectaformis*, *Robulus carinocordatus*, *Saracenaria malaviyai*, *Vaginulina pseudotruncana*, *V. renomina*, *V. subharpa*, *Citharina pseudolatissima*, *Citharinella foliaformis*, *Epistomina ghoshi*, *Epistomina* (*Brotzenia*) *khawdensis*, *Reinholdella quadrilocula*, *Trocholina conosimilis*, and *Dorothia poddari*. They proposed a Callovian to Oxfrodian age for the studied sequence on the basis of foraminiferal assemblages.

After Subbotina's (1960) detailed study, it took nearly fifteen years for the first serious reserach work on Jurassic foraminifera to be initiated by the first author and his co-workers at the Micropapaeontology Lab, Department of Geology, Aligarh Muslim Univrsity, Aligarh who published detailed accounts of systematics, biostratigraphy, palaeoecology, and palaeozoogeography of Jurassic foraminifera from Kutch Mainland recovered from Jara, Jumara, Kaiya, Keera, Jhurio, Fakirwadi, and Ler domes in a series of publications since 1975.

FORAMINIFERAL COMPOSITION

Table 1. displays the list of all the foraminiferal species (507) so far reported from this region including 41 species newly added to the foraminiferal literature, 347 species reported for the first time from the Indian subcontinent and 119 indeterminate species which could not be assigned a trivial name due to scarce specimens and may be new species.

Generally, the foraminiferal composition of all the domes of Kutch is dominated by vaginulinids and nodosariids. Both calcareous and agglutinated forms are present in the assemblages and the average ratio between calcareous and agglutinated forms is 1:2.67. In addition, Kutch Mainland assemblages include fairly rich epistominid species which are considered as one of the most important group of Benthic Foraminifera for Jurassic biostratigraphy, having reticulate and non-reticulate forms. The Kutch Mainland foraminiferal material also exhibits a high degree of inter- as well as intra-specific variation as observed in nodosariids and vaginulinids by the researchers at the Micropalaeontology Lab, Department of Geology, Aligarh Muslim University, Aligarh.

BIOSTRATIGRAPHY

Eight domed outcrops from Kutch Mainland and one from Pachchham 'Island' (Northern Island Belt, Rann of Kutch) have been investigated for foraminifera (Fig. 1). In the Kutch Mainland these sections are located in Jara, Jumara, Jhurio, Keera, Nara, and Habo domes north of Bhuj, the district headquarter of the Kutch region and Ler and Fakirwadi domes south of Bhuj whereas in the Northern Island Belt sections are located in the Pachchham Island. Studied foraminiferal assemblages have been employed to interpret age (Subbotina *et al*., 1960; Bhalla and Abbas 1975a, b, c, 1976a; Bhalla and Talib 1978, 1980; Bhalla and Lal 1985; Mandwal and Singh 1989; Bhalla and Talib 1985a, b, c, 1991; Bhalla and Gaur, 1987; Gaur and Talib, 2009; Mandwal and Singh, 1994; Talib and Faisal, 2006; Talib and Faisal, 2007; Talib *et al*., 2012a, 2017; Talib *et al*., 2012b; Al-Hussein 2014; Talib *et al*., 2016; Bhat *et al*., 2016; Talib *et al*., 2017; Wasim *et al*., 2017) and work out biozonation (Pandey and Dave, 1993; Gaur and Sisodia, 2000; Gaur and Singh, 2000; Talib *et al*., 2017b) of the rocks exposed in these domes and are being described in detail below:

Jara Dome is located on western side of the Kutch Mainland, and yielded a total of 51 species (Wasim *et al*., 2017; Tirvedi, 2004). Most of the species in the studied section are long-ranging. However, there are a few comparatively short-ranging foraminiferal species restricted within a single stage, most representative of Callovian. Species globally confined to Callovian are *Frondicularia* aff. *F. pseudoconcinna*, *Marginulina batrakiensis*, and *Citharinella* aff. *C. compara*. Furthermore, *Lenticulina staufensis* and *Astacolus pauperatus* have not been recorded in strata younger than Callovian. In the Indian region, fifteen species are found to occur within Callovian strata, *viz*., *Dentalina communis*, *Frondicularia* cf. *pseudoconcinna*, *Lenticulina audax*, *L. nodosa*, *Marginilina batrakiensis*, *Marginulina simplex*, *Pyramidulina amphioxys*, *Reophax tener*, *Triplasia emslandensis*, *Tristix suprajurassica*, *Vaginulinoposis enodis*, and *V. epicharis*. In view of the above, a Callovian age is assigned to the rocks of Jara Dome on foraminiferal evidence.

Jumara dome is located east of Jara in western Kutch. Pandey and Dave (1993), Bhalla and Gaur (1987), Talib and Gaur (2005), Gaur and Talib (2009), Al-Hussein (2014), and Wasim (2015) studied foraminifera of this dome. The numbers of foraminiferal species described from this section

Table 1. Jurassic foraminiferal species including new, first time reported from Indian region, and marker species reported from Kutch.

S.No.	Foraminiferal Species
1	Agathammina sp.
2	Ammobaculites ahmadi $
3	*Ammobaculites alaskensis $@
4	*Ammobaculites albertensis $@
5	*Ammobaculites areniferus $@
6	*Ammobaculites auricularis $@
7	*Ammobaculites bivarians $@
8	*Ammobaculites cobbani $
9	*Ammobaculites coprolithiformis #$
10	*Ammobaculites aff. A. culmulus $@
11	*Ammobaculites elenae $@
12	*Ammobaculites fisheri $
13	*Ammobaculites fontinensis $
14	*Ammobaculites formosus
15	*Ammobaculites glaessneri #
16	**Ammobaculites gowdai Bhalla & Abbas $@
17	**Ammobaculites hagni Bhalla & Abbas $@
18	*Ammobaculites imlayi $@
19	*Ammobaculites irregulariformis $@
20	*Ammobaculites magharaensis $@
21	*Ammobaculites nannogyra #$
22	*Ammobaculites aff. A. natruriensis $
23	*Ammobaculites reophaciformis $
24	*Ammobaculites reophacoides $@
25	Ammobaculites sp. A #
26	Ammobaculites sp. B #
27	Ammobaculites sp. C $
28	Ammobaculites sp. H @
29	Ammobaculites sp. E
30	Ammobaculites sp. F
31	Ammobaculites sp. G
32	*Ammobaculites subcretaceous
33	*Ammobaculites suprajurassicum
34	*Ammobaculites torosus $
35	*Ammobaculites aff. A. variablis @
36	**Ammodiscus gowdai Bhalla & Abbas $@
37	*Ammodiscus asper
38	*Ammodiscus siliceus
39	Ammodiscus sp. A $
40	Ammodiscus sp. B $
41	*Ammomarginulina cragini $
42	*Astacolus anceps
43	*Astacolus aphrastus
44	*Astacolus beierana $
45	*Astacolus centralis $@
46	*Astacolus centrogyrata $
47	*Astacolus clava $
48	*Astacolus crepidula $
49	*Astacolus filose $
50	*Astacolus instabilis #
51	*Astacolus pauperatus $@
52	*Astacolus aff. A. pellusida $
53	*Astacolus renomina $
54	Astacolus sp. A #
55	Astacolus sp. B @
56	Astacolus sp. C
57	Astacolus sp. D
58	Astacolus sp. E
59	*Astacolus stilla $
60	*Astacolus subinvoluta #
61	Bathysiphon sp. A #
62	Bathysiphon sp. B #$
63	Bigenerina sp. A $
64	Bigenerina sp. B
65	*Bojarkaella firma $
66	*Bolivina incrassate $
67	Brizalina sp. A $
68	Brizalina sp. B
69	*Brotzenia khawdensis
70	*Bulbobaculites lueckei $@
71	*Bulbobaculites reophacoides $@
72	*Bulbobaculites vermiculus $
73	*Bulbobaculites willowensis @
74	*Citharina clathrata
75	*Citharina colliezi
76	*Citharina decemcostata $
77	*Citharina entypomatus
78	*Citharina flabellata $
79	*Citharina gibbosa $
80	*Citharina hetropleura #$
81	*Citharina inconstans$
82	*Citharina aff. C. latissima
83	** Citharina pseudolatissima Subbotina et al. @
84	*Citharina rudocostata
85	*Citharina serratocostata $
86	Citharina sp. A @
87	Citharina sp. B @
88	Citharina sp. C #$
89	Citharina sp. D
90	Citharina sp. E
91	Citharina sp. F
92	*Citharina sparsicostata #
93	** Citharina subharpa Subbotina et al. $
94	*Citharina zaglobensis $
95	*Citharinella aff. C. compara
96	** Citharinella foliaformis Subbotina et al. $
97	*Citharinella latifolia $@
98	*Citharinella rhomboidea
99	*Cornuspira orbicula #
100	*Dentalina communis $
101	*Dentalina filiformis ^
102	*Dentalina aff. D. sarthacensis
103	Dentalina sp. A
104	Dentalina sp. B
105	** Dobrogelina rajnathi Pandey & Dave @
106	*Dorothia prekummi $@
107	*Eoguttulina liassica $@

108 *Eoguttulina oolithica* **$**
109 *Eoguttulina polygona* **$@**
110 **Epistomina alveolata*
111 **Epistomina antorolavaensis* **$**
112 **Epistomina bireticulata* **#$**
113 **Epistomina* aff. E. *caracolla* **@**
114 **Epistomina charlottae* **@**
115 **Epistomina coronate*
116 **Epistomina costifera*
117 **Epistomina cretosa* **$@**
118 *Epistomina dilecta* **$@**
119 **Epistomina elschankaensis* **$**
120 ** *Epistomina ghoshi* Subbotina et al. **#$**
121 **Epistomina gracilis* **$**
122 ** *Epistomina khawdensis* Pandey & Dave
123 **Epistomina lacunose* **$**
124 **Epistomina limbata*
125 **Epistomina madagascariensis* **@**
126 **Epistomina majungaensis* **@**
127 **Epistomina minutereticulata* **@**
128 **Epistomina mosquensis*
129 **Epistomina nuda* **#**
130 ** *Epistomina paraghoshi* Subbotina et al.v**@**
131 **Epistomina parastelligera* **$**
132 **Epistomina peregraina* **$**
133 **Epistomina praemajungaensis* **@**
134 **Epistomina praereticulata* **$**
135 ** *Epistomina preventriosa* Subbotina et al.
136 ** *Epistomina pseudocaracolla* Subbotina et al **$@**
137 ** *E. pseudostellicostata* Pandey & Dave **$**
138 ** *Epistomina punctata* Subbotina et al. **$@**
139 **Epistomina regularis*
140 *Epistomina* sp. A **$**
141 *Epistomina* sp. B **$**
142 *Epistomina* sp. C
143 *Epistomina* sp. D
144 *Epistomina* sp. E
145 *Epistomina* sp. F
146 *Epistomina* sp. G
147 **Epistomina spinulifera polypioides*
148 **Epistomina stellicostata* **$@**
149 **Epistomina stelligera*
150 **Epistomina tenuicostata* **@**
151 **Epistomina turgidula* **#**
152 **Epistomina volgensis volgensis* **@**
153 **Falsopalmula* aff. F. *centralis* **$**
154 **Falsopalmula deslongchampsi* **$@**
155 **Falsopalmula jurensis* **$**
156 **Falsopalmula* aff. F. *primordialis* **$**
157 **Flabellammina alexandri* **$**
158 **Flabellammina althoffi* **#$**
159 ** *Flabellammina bharatica* Bhalla & Talib **$**
160 **Flabellammina chapmani* **$**
161 **Flabellammina lidae*
162 **Flabellammina macfadyeni* **$@**
163 **Flabellammina magna* **$**
164 **Flabellammina reynoldsi* **$**
165 *Flabellammina* sp. A
166 *Flabellammina* sp. B
167 **Flabellammina vitrea*
168 **Frondicularia franconica* **$**
169 **Frondicularia involuta* **$@**
170 **Frondicularia kuldharensis*
171 ** *Frondicularia kutchensis* Bhalla & Abbas **$@**
172 **Frondicularia lignaria* **$**
173 **Frondicularia nodosaria* **$**
174 **Frondicularia* aff. F. *pseudoconcinna* **$**
175 *Frondicularia* sp. A
176 **Garantella* aff. *G. stellata* **#**
177 **Garantella ornata* **#**
178 *Garantella* sp. A **#$**
179 *Gaudrinella* sp. B
180 **Gaudryina descrita*
181 *Gaudryina* sp. A
182 **Globigerina* aff. *G. oxfordiana* **@**
183 **Globuligerina balakhmatovae*
184 *Globuligerina* sp.
185 **Glomospira* aff. G. *perplexa*
186 **Glomospira* aff.G. *reversa*
187 **Glomospira gordialis*
188 **Grigelis apheilolocula* **$**
189 **Haplophragmium aequale*
190 **Haplophragmium inconstans*
191 ** *Haplophragmoides agrawali* Bhalla & Abbas **$@**
192 **Haplophragmoides bartensteini* **$**
193 **Haplophragmoides concavus*
194 **Haplophragmoides fraseri* **$**
195 **Haplophragmoides kinganensis* **@**
196 ** *H. kutchensis* Pandey & Dave **$**
197 **Haplophragmoides* aff. H. *laminates* **$**
198 **Haplophragmoides latidorsetim* **$**
199 **Haplophragmoides rajnathi* Bhalla & Abbas **$@**
200 **Haplophragmoides srivastavi* Bhalla & Abbas **$@**
201 **Haplophragmoides tewarii* Bhalla & Abbas **$@**
202 *Haplophragmoides* sp. A
203 *Haplophragmoides* sp. B
204 *Hemidiscus* sp.
205 **Hemirobulina curvatura* **$@**
206 **Hemirobulina planitesta* **@**
207 ** *Hemirobulina sastryi* Bhalla & Abbas **$@**
208 **Hemirobulina simplex*
209 **Ichthyolaria* aff. I. *baueri* **$**
210 **Ichthyolaria longiscata* **#$**
211 **Kutsevella spilota* **$**
212 **Laevidentalina arbuscula*
213 **Laevidentalina bullata* **$@**
214 **Laevidentalina gümbeli*
215 **Laevidentalina jurensis* **$@**
216 **Laevidentalina nana* **$**
217 **Laevidentalina* aff. *L. oppeli* **$**

218 **Laevidentalina propinqua* **$**
219 **Laevidentalina* aff. L. *sarthacensis* **$**
220 **Laevidentalina* aff. L. *subguttifera* **$@**
221 *Laevidentalina* sp.
222 **Lagena globosa*
223 **Lagena ovata*
224 *Lagena* sp. A **$**
225 *Lagena* sp. B **$**
226 *Lagena* sp. C
227 **Lagena sulcata*
228 **Lagenammina difflugiformis*
229 **Lagenammina pseudodifflugiformis***$@**
230 **Lenticulina andromede* **$**
231 **Lenticulina aquilonica* **@**
232 **Lenticulina* aff. L. *atheria* **$@**
233 **Lenticulina argonauta* **$**
234 **Lenticulina audax* **$**
235 **Lenticulina brueckmanni* **$**
236 **Lenticulina bulla*
237 *Lenticulina carinocordatus* **@**
238 **Lenticulina centralis* #
239 **Lenticulina desnaensis* **$**
240 ** *Lenticulina dilectaformis* Subbotina et al.
241 **Lenticulina discipiens*
242 **Lenticulina ectypa* **$**
243 **Lenticulina gaultina* **$@**
244 **Lenticulina* aff. L. *humilis*
245 **Lenticulina jurassica* **$@**
246 *Lenticulina* aff. L. *lideri* **@**
247 **Lenticulina muensteri*
248 **Lenticulina nodosa* **$**
249 **Lenticulina ouachensis* **$**
250 **Lenticulina polonica* **$**
251 **Lenticulina polygonata*
252 **Lenticulina protracta*
253 **Lenticulina quenstedti*
254 ** *Lenticulina rajnathi* Pandey & Dave
255 *Lenticulina* sp. A **$**
256 *Lenticulina* sp. B **$**
257 *Lenticulina* sp. C **$**
258 *Lenticulina* sp. D **@**
259 *Lenticulina* sp. E **@**
260 *Lenticulina* sp. F **@**
261 **Lenticulina staufensis*
262 **Lenticulina subalata*
263 **Lenticulina subtilis* **$**
264 ** *Lenticulina suturifusus* Bhalla & Abbas
265 **Lenticulina tricarinella*
266 *Lenticulina toarcense* **@**
267 **Lenticulina varians*
268 **Lenticulina vetusta elongate* **$@**
269 *Lenticulina vistulae* **@**
270 **Lingulina cemua* **$**
271 **Lingulina esseyana* **$**
272 **Lingulina laevissima*
273 **Lingulina lanceolata* **$**
274 **Lingulina longiscata*
275 **Lingulina nodosaria*
276 *Lingulina sp. A*
277 **Marginulina batrakiensis* **$**
278 **Marginulina buskensis* **$**
279 **Marginulina coelata* **$@**
280 **Marginulina cryptospira*
281 **Marginulina curvature* **$@**
282 ** *Marginulina haynesi* Bhalla & Abbas
283 ** *Marginulina jumaraensis* Bhalla & Gaur **$@**
284 **Marginulina oolithica*
285 **Marginulina oxfordiana*
286 **Marginulina paucicosta* **$**
287 **Marginulina planitesta* **@**
288 **Marginulina reti*
289 ** *Marginulina sastryi* Bhalla & Talib **$@**
290 **Marginulina sculptilis* **$**
291 **Marginulina simplex* **$**
292 **Marginulina stratifera* **$**
293 *Marginulina* sp. A **$**
294 *Marginulina* sp. B **$**
295 *Marginulina* sp. C
296 *Marginulina* sp. D
297 *Marginulina* sp. E
298 *Marginulina* sp. F
299 **Marginulina tenuissima* **$**
300 **Marginulinopsis instabilis* **$@**
301 **Marginulinopsis* aff. *M. mjatjukae*
302 **Marginulinopsis* aff. *M. stephensoni*
303 *Marginulinopsis sp. A* **$**
304 *Marginulinopsis sp. B*
305 **Mesodentalina matutina* **$**
306 **Neoflabellina ovalis* **$@**
307 **Neoflabellina rhomboidea* #
308 **Neoflabellina sp.*
309 **Nodosaria apheilolocula*
310 **Nodosaria bioloculina*
311 **Nodosaria* aff. *corallina* **$**
312 **Nodosaria cylindracea* **@**
313 **Nodosaria cyclindracea costa* **$**
314 **Nodosaria* aff. *N. columnaris* **$**
315 **Nodosaria daedala* **@**
316 *Nodosaria dentticulata costata* **@**
317 **Nodosaria dispar* **$**
318 **Nodosaria elegantia* **$**
319 **Nodosaria fontinensis* #**$**
320 **Nodosaria fusiformis* ^
321 **Nodosaria hortensis*
322 **Nodosaria larina* **@**
323 **Nodosaria lirulata*
324 **Nodosaria marginata* **$@**
325 **Nodosaria mecista* **$@**
326 **Nodosaria mitis* **$**
327 **Nodosaria oligostegia* **$**

328 **Nodosaria radiate* **$**
329 *Nodosaria rigentia* **@**
330 **Nodosaria simplex*
331 **Nodosaria sowerbyi*
332 *Nodosaria tenera* **@**
333 *Nodosaria* sp. A $
334 *Nodosaria* sp. B **@**
335 *Nodosaria* sp. C **$@**
336 **Nubeculinella bigoti* **$@**
337 **Ophthalmidium carinatum* ^
338 **Ophthalmidium* aff. *tanuissimum* **$**
339 **Ophthalmidium strumosum*
340 *Paalzowella* sp.
341 **Paleogaudryina magharaensis*
342 *Paleomiliolina* sp.
343 **Palmula deslongchampsis* ^
344 ***Patellinella poddari* Subbotina et al.
345 **Patellina subcretacea* #**$**
346 **Planularia tricarinella*
347 **Praelamarckina humilis* #
348 ***Praelamarckina pseudorjasanensis* Pandey & Dave #**$**
349 **Pravoslavlevia vestita* **$@**
350 **Prodentalina gümbeli*
351 **Proteonina difflugiformis* **$**
352 **Psamminopelta bowsheri* **$**
353 *Pseudoglandulina* sp. A **$**
354 *Pseudomarssonella* sp. B
355 **Pseudomarssonella biangulata* #
356 **Pseudomarssonella inflata* #
357 **Pseudomarssonella plicata* #
358 **Pseudomarssonella primitive* #
359 **Pseudomarssonella reflexa* #
360 **Pseudonodosaria sowerbyi* **$**
361 **Pseudonodosaria vulgata* **$**
362 **Pseudonodosaria* sp. **@**
363 *Pseudolamarkina* sp. **@**
364 **Psilocitharella leptoteicha* **$**
365 **Pyramidulina amphioxys* **$**
366 **Pyramidulina* aff. P. *columnaris*
367 **Pyramidulina coralline*
368 **Pyramidulina dispar*
369 **Pyramidulina* aff. P. *fontinensis*
370 **Pyramidulina hortensis*
371 **Pyramidulina opalini*
372 **Pyramidulina* aff . P. *paupercula*
373 **Pyramidulina radiata*
374 **Pyramidulina rara*
375 **Pyramidulina sculpta*
376 *Pyramidulina sp. A*
377 *Pyramidulina sp. B*
378 *Quinqueloculina sp. B* **@**
379 *Quinqueloculina sp. C* **@**
380 **Ramulina abscissa*
381 **Ramulina apheilolocula* **$**
382 **Rectogulandulina tenuis*
383 **Rectogulandulina vulgata*
384 ***Reinholdella quadrilocula* Subbotina et al. **$**
385 **Reophax agglutinans*
386 **Reophax coonensis* #
387 **Reophax densa* **$**
388 **Reophax helveticus* **@**
389 **Reophax hounstoutensis* **$@**
390 **Reophax ismaili* #
391 **Reophax metensis* **$**
392 **Reophax multilocularis*
393 **Reophax reophacoides*
394 *Reophax* sp. A **$**
395 *Reophax* sp. B
396 *Reophax* sp. C
397 *Reophax* sp. D
398 *Reophax* sp. E
399 **Reophax* aff. *R. scorpiurus* **$**
400 **Reophax sterkii*
401 **Reophax subgoodlandensis* **$@**
402 **Reophax sundancensis* **$@**
403 **Reophax tener* **$**
404 **Reophax variabilis* **$**
405 **Riyadhella elongate* #
406 ***Robulus carinocordatus* Subbotina et al. **$**
407 **Saccammina* aff. *S. franconica* **$**
408 **Saracenaria cornucopiae*
409 *** Saracenaria malaviyai* Subbotina et al. **$**
410 **Saracenaria oxfordiana* **$**
411 *Saracenaria* sp. A **@**
412 ***Saracenaria tripartita* Subbotina et al.
413 **Saracenaria triquetra*
414 **Sculptobaculites goodlandensis* **$**
415 ***Singhamina jaisalmerensis* Garg & Singh #
416 ***Singhamina rajasthaensis* Garg & Singh #
417 **Sorosphera robusta*
418 **Spirillina amphelicta* **@**
419 **Spirillina andreae*
420 **Spirillina elongata* #
421 *Spirillina gracilis***@**
422 **Spirillina orbicula*
423 **Spirillina pogyrata*
424 **Spirillina radiata*
425 ***Spirillina tenuicostata* Subbotina et al. **$**
426 **Spirillina tenuissima*
427 **Spiroplectammina biformis* #
428 **Spiroplectammina longa* **@**
429 *Spiroplectammina* sp. A **$**
430 *Spiroplectammina* sp. B
431 *Subdelloidina* sp.
432 ***Tandonina paula* Garg & Singh #
433 **Tewari kutchensis* #**$**
434 **Textulara jurassica* **$@**
435 **Textularia pugiunculus* **$**
436 **Thurammina diaforamens* **$**

437 **Tribrachia inelegans*
438 *Triloculina* sp. A **@**
439 *Triloculina* sp. B **@**
440 *Trochammina* sp. A
441 **Triloculina variabilis*
442 **Triplasa emslandensis*
443 **Triplasia althoffi* **$**
444 **Triplasia althofi jurassica*
445 **Triplasia australiae*
446 *Triplasia bartensteini* **#$**
447 *Triplasia emslandensis* **$**
448 *Triplasia kingakensis* **$**
449 *Triplasia* sp. A **$@**
450 *Triplasia* sp. B
451 *Trisegmentina* sp.
452 *Tristix oolithica*
453 *Tristix suprajurassica* **$**
454 *Tristix triangularis*
455 *Trochammina* aff. *T. concave*
456 *Trochammina gryci*
457 *Trochammina* sp. A @
458 *Trochammina* sp. B
459 *Trocholina conica*
460 ***Trocholina conosimilis* Subbotina et al.
461 *Trocholina nodulosa @*
462 **Trocholina solecensis*
463 *Trocholina sp.* A #
464 *Trocholina sp.* B **$**
465 *Trocholina sp.* C
466 **Tubinella inornata*
467 **Vaginulina ancipitana* **$**
468 **Vaginulina barnardi*
469 ***Vaginulina bhatiai* Bhalla & Talib **$@**
470 **Vaginulina compsa*
471 **Vaginulina cryptospyra @*
472 **Vaginulina hybrid* **$@**
473 **Vaginulina inspissata* **$@**
474 **Vaginulina kochi @*
475 **Vaginulina lechriosa @*
476 **Vaginulina misrensis* **$@**
477 **Vaginulina orthonota* **$@**
478 **Vaginulina proxima* **$**
479 **Vaginulina pseudocrepidula* **$**
480 ***Vaginulina pseudotruncana* Subbotina et al. **$**
481 ***Vaginulina renomina* Subbotina et al. **$@**
482 *Vaginulina* sp. A
483 *Vaginulina* sp. B @
484 *Vaginulina* sp. C @
485 *Vaginulina* sp. D
486 ***Vaginulina subharpa* Subbotina et al. **$**
487 ***Vaginulina woodi* Bhalla & Abbas
488 **Vaginulinopsis aduncus*
489 **Vaginulinopsis arimensis@*
490 **Vaginulinopsis* aff. *V. bartensteini* **$**
491 **Vaginulinopsis ectypa* **$**
492 **Vaginulinopsis enodis* **$@**
493 **Vaginulinopsis epicharis* **$**
494 **Vaginulinopsis eritheles*
495 **Vaginulinopsis incisiformis* **$**
496 **Vaginulinopsis instabilis* **$@**
497 **Vaginulinopsis longestriata* **$**
498 **Vaginulinopsis misrensis* **#$**
499 *Vaginulinopsis* sp. A @
500 *Vaginulinopsis* sp. B
501 *Vaginulinopsis* sp. C
502 **Vaginulinopsis stephensoni*
503 **Vaginulinopsis stilla* **$**
504 *Vaginuluna* sp.
505 **Verneuilinoides subvitreus*
506 **Verneuilinoides tryphera @*
507 **Vinelloidea* aff. *V. bigoti*

LEGEND
**** Newly erected species from Kutch with Author**
*** First time reported in India**

507	**TOTAL SPECIES**
41	**(**) First time reported in world (New Species)**
347	**First time reported in India**
119	**Indeterminate species**
88	**Identified genera**

MARKER SPECIES

^	Bajocian	05 Species
#	Bathonian	29 Species
$	Callovian	159 Species
@	Oxfordian	61 Species
#$	Bathonian to Callovian	19 Species
$@	Callovian to Oxfordian	73 Species
	Single Stage	254 Species
	Double Stage	92 Species

are 219 with 88 restricted to single stage, five in Bajocian, five in Bathonian, sixty-one in Callovian and seventeen in the Oxfordian. On the other hand, fifty four are reported to confine to two stages. Thus, fourteen species are confined to Bathonian and Callovian whereas forty to Callovian and Oxfordian. On the basis of their regional as well as global occrrences, the Jumara rocks are assigned Upper Bathonian to Early Oxfordian age. Foraminiferal biozones of Upper Bathonian (*Dobrogelina rajnathi* Range Zone), Callovian (*Lenticulina decipiens* Zone, *T. kutchensis* Partial Range Zone, Proteonina *difflugiformis* - *Astacolus anceps* Assemblage Zone) and Early Oxfordian age (*E. majungaensis* Range Zone, *E. Majungaensis* - *L. bulla* Inter biohorizon Zone) are marked by Pandey and Dave (1993).

Nara Dome (Kaiya Hill) Foraminifera of this dome are investigated by Bhalla and Lal (1985), Gaur and Singh (2000) and Talib *et al*. (2012 a) which is located in the centre of the Kutch Mainland. The reported foraminiferal assemblage includes 65 species, having 22 species restricted in single stage, of which 18 are confined to Callovian and four to Oxfordian. However, a number of fairly short-ranging species are either restricted to or frequently reported from Callovian-Oxfordian strata of theIndian region. These include *Ammobaculites gowdai*, *A. irregulariformis*, *Astacolus pauperatus*, *Citharinella latifolia*, *Epistomina cretosa*, *Frondicularia involuta*, *F. kutchensis*, *Lenticulina gaultina*, *Nodosaria marginata*, *Reophax subgoodiandensis*, *R. sundancensis*. Four biozones, *viz*., *Spirillina polygyrata-Lenticulina-Citharina clathrata*

Assemblage Zone, *Epistomina mosquensis* Assemblage Zone, *Flabellammina* sp.-*Triplasia emsalandensis* Assemblage Zone, and *Astacolus anceps*-*Epistomina alveolata* Assemblage Zone, were identified within the Callovian-Oxfordian succession on the basis of the foraminiferal assemblages. On the basis of the recovered species a possible Callovian to Oxfordian age is suggested for the studied sequence of the Chari Formation exposed at Kaiya Dome, Kutch.

Keera Dome is exposed in the middle of the Kutch Mainland, east of Kaiya Dome. Gaur and Sisodia (2000) and Talib *et al*. (2012 b) reported 54 foraminiferal species. 12 species are restricted to a single stage with ten, *viz, Ammobaculites reophaciformis*, *Astacolus filose*, *Citharina zaglobensis*, *Lenticulina nodosa*, *Pseudonodosaria sowerbyi*, *Reophax tener*, *Triplasia emslandensis*, and *Vaginulinopsis enodis* in Callovian and two, *viz*, *Citharina entypomatus* and *Nodosaria larina* in Oxfordian. Some of the species, *viz*., *Ammobaculites alaskensis*, *A. gowdai*, *A.hagni*, *A.irregulariformis*, *Astacolus pauperatus*, *Epistomina stellicostata*, *Frondicularia kutchensis*, *Haplophragmoides tewarii*, *Lagenammina pseudodifflugiformis*, *Lenticulina gaultina*, *Nodosaria mecista*, and *Vinelloidea* aff. *V. bigoti* occur in both Callovian and Oxfordian stages. The studied sequence has been divided by Gaur and Sisodia (2000) into seven biozone on the basis of dominancy of the species. Early Callovian is represented by the Barren Zone; Middle Callovian divided in four biozones, *viz, Planularia tricarinella* - *Lenticulina quenstedti* Assemblage Zone, *Spirillina polygurata* - *Planularia tricarinella* Assemblage Zone, *Ammobaculites alaskensis* - *Triplasia emslandensis* Assemblage zone, and *Ammobaculites alaskensis* - *Triplasia jurassica* Assemblage zone, and Upper Callovian and Oxfordian are represented by *Epistomina mosquensis* - *Planularia tricarinella* and *Citharina zaglobensis* - *Planularia tricarinella* Assemblage zones respectively. Later Talib *et al*., (2017a) marked seven foraminiferal biozones which were compared with the ammonite zones. Early Callovian is represented by the Barren Zone due to absence of forminifera; Middle Callovian divided in four biozones, *viz*, *Planularia tricarinella*- *Lenticulina quenstedti* Assemblage Zone, *Spirillina polygyrata* - *Planularia tricarinella* Assemblage Zone, *Ammobaculites alaskensis*- *Triplasia emslandensis* Assemblage Zone, *Ammobaculites alaskensis* - *Triplasia althoffi jurassica* Assemblage Zone; Upper Callovian and Early Oxfordian are represented by *Epistomina mosquensis* - *Planularia tricarinella* and *Citharina zaglobensis* - *Planularia tricarinella* Assemblage zones respectively.

Jhurio Dome is located to the west of Badi village, towards northwest of Bhuj in Kutch Mainland. Bhalla and Talib (1980), Pandey and Dave (1993), Mandwal and Singh (1994), Bhalla and Talib (1991), Talib and Bhalla (2006a) and Al-hussein (2014) studied this dome and reported a total of 169 Foraminiferal species as revealed from different publication on the said dome, with 62 restricted to single stage, one in Bajocian, sixteen in Bathonian, thirty in Callovian and fifteen in Oxfordian. Twenty-three species range within two stages with eight species found to occur in Bathonian to Callovian and fifteen species in Callovian to Oxfordain. On the basis of their occurrences regionally as well as globally the Jhurio rocks are assigned Bathonian to Oxfordian age. Pandey and Dave (1993) divided the studied sequence at Jhurio into four Zones. These include Bathonian (*Epistomina regularis* - *Epistomina ghoshi* Assemblage Zone, *Lenticulina dilectaformis* Partial Range Zone); Callovian (*Tewaria kutchensis* Partial Range Zone), and Oxfordian (*Epistomina majungaensis* Range Zone and *E. majungaensis*-*Lenticulina bulla* Inter Biohorizon or Interval Zone.

Habo Dome is located in western part of the Kutch Mainland and invetigated by Subbotina *et al*. (1960), Bhalla and Abbas (1978), Pandey and Dave (1993), and Talib *et al*. (2016; 2017a). 168 species are repored and the foraminiferal assemblages suggest Bathonian to Oxfordian age. Pandey and Dave (1993) marked four foraminiferal biozones within the studied sequence which are *Lenticulina decipiens* Zone, *E. majungaensis* Range Zone, *E. Majungaensis* - *Lenticulina bulla* Interbiohorizon, and *Lenticulina bulla* Partial Range Zone. In the studied section 81 foraminiferal species are short ranging confined to a single stage. Of these, 11 species, *viz*, *Ammobaculites glaessneri*, *Ammobaculites* sp., *Ammobaculites* sp. *B*., *Astacolus* sp., *Citharina sparsicostata*, *Cornuspira orbicula*, *Neoflabellina rhomboidea*, *Pseudomarssonella plicata*, *Reophax coonensis*, *Reophax ismaili*, *Spiroplectammina biformis* are restricted to Bathonian both globally as well as regionally. Fifty species are restricted to Callovian wheres twenty to Oxfordian. Thirty-two species are restricted within two satges. Out of these, nine range from Bathonian to Callovian and twenty-three from Callovian to Oxfordian. On the basis of these marker species, Habo Dome sequence is assigned a Bathonian to Oxfordian age.

Fakirwadi Dome is located near Bhuj, the district headquater of Kutch. Talib and Faisal (2006) and Bhat *et al*. (2016) reported fifty-two species, most of which are long ranging. Twenty-two are restricted in single stage, nineteen in Callovian and three in Oxfordian. The species *Frondicularia kuldharensis*, *Lenticulina decipiens*, *Marginulina batrakiensis* and *Citharinella* aff. *C. compara* are restricted to the Callovian either globally or in the Indian region. *Reophax metensis*, *Ammobaculites fontinensis* and *Epistomina* aff. E. *regularis* occurring in the present assemblages have not been recorded in strata younger than the Callovian throughout the world. Based on the foraminiferal assemblages, the studied sequence of the Chari Formation of Fakirwari Dome is assigned a Callovian age.

Ler Dome near Bhuj is studied by Talib and Faisal (2007) which yielded a total of 40 foraminiferal species, amongst them seventeen species are reported from a single stage, sixteen in Callovian and one in Oxfordian. Seven of the species are restricted in both Callovian and Oxfordian stages and rest are long ranging. Therfore, a Callovian to Oxfordian age is assigned to the Ler sequence on the basis of the recovered species.

Pachchham Island: is located in northern Kutch and Khavada Nala Section located about 1 km east of Khavda village, yielded ninteen species and dated as Bathonian (*E. regularis*-*E. ghoshi* Assemblage Zone) by Pandey and Dave (1993) whereas rocks in Gorandongar Section, having twenty species, are assigned a Bajocian/Bathonian and Callovian age with the help of some restricted species such as *Ammobaculites fontinensis*; *Astacolus beierana*; and *A. stilla by* (Varshney, 2006).

It is desirable to establish marker Middle and Late Jurassic foraminiferal species in the Indian region for biostratigraphical use. Most of the species reported are long ranging but several short-ranging species have been identified which are resrticted to one or two stages. 256 species are restricted to a single stage, 5 in Bajocian, 29 in Bathonian, 159 in Callovian, and 61 in Oxfordian. 92 species are restricted within two stages, whereas 19 species range from Bathonian to Callovian and 73 from Callovian to Oxfordian in the Indian region and some of the species are restricted to single as well as double stages globally. On the basis of marker species, Patcham and Chari formations of the Kutch Jurassics are assigned Bathonain to Oxfordian age. (Table 1).

Megafossils of ammonites and belemnites have been used for dating the Patcham and Chari formations in different Jurassic outcrops of the Kutch basin by various researchers including Cox, 1940, 1952; Krishna, 1987; Bardhan *et al*., 1994, 2010; Jain and Pandey 1997; Jain and Pandey 1997; Krishna *et al*., 2000; Jana *et al*., 2005; Desai and Patel 2009; and Jana *et al*., 2005; Jain and Desai 2014 and Jain 2014 which suggest Patcham and Chari formations of Kutch range from Late Bajocian to Lower Oxfordian. Rai and Jain (2013) suggests on the basis of nannofossil and ammonites that both the formations range from Middle Bathonian to Early Oxfordian.The studies based on foraminifera suggests a Upper Bathonian to Lower Oxfordian age for the Patcham and Chari Formations (Bhalla and Talib, 1991; Pandey and Dave, 1993; Talib *et al*., 2007; Gaur & Talib, 2009; Bhat *et al*., 2016; Talib *et al*., 2016; 2017a,b) The compilation and comparison of both the megafaunal and foraminiferal studies so far carried out on Jurassic of Kutch appears to be more or less in conformity with regard to the age.

PALAEOECOLOGY AND DEPOSITIONAL ENVIRONMENT

Early studies on Jurassic foraminifera reveal that they are not very reliable for reconstruction of an accurate palaeoecological model (Natland, 1957; Phleger, 1960; Ager, 1963; Gaur and Talib 2009; Bhalla and Abbas, 1987; Gaur and Talib 2009). This may be because of the fact that certain group of Mesozoic foraminifera, especially Vaginulinds and Nodosarrids have changed their habitat since post-Cretaceous times migrating from shallow to deeper waters (Barnard 1948; Bhalla and Abbas, 1978). In addition to that there is paucity of precise ecological data on individual Jurassic foraminiferal species as most of the microfauna have become non-extant. Thus, it appears that the foraminiferal assemblages obtained from Jurassic sediments of Kutch Mainland may not be significant for accurate paleoecological reconstruction. Therefore, in these studies the foraminifera have been employed in a rather generalized manner and supported by other parameters such as lithofacies, microfacies, megafossils and field evidences. However, in some of the more recent studies in different parts of the world fairly accurate palaeoecological interpretations employing Jurassic foraminifera have been attempted (Koutsoukos 1990; Nagy1992; Tyszka 1994; Valchev 2003; Canales and Henriques 2008; Canales *et al*., 2014; and Reolid *et al*., 2008a, b; 2010; 2012; Ghoorchaei *et al*., 2012) including the Kutch Jurassics (Talib *et al*., 2016, 2017a; Bhat *et al*., 2016 and Wasim *et al*., 2017). This was possible by applying some relatively recent techniques of palaeoecological interpretations using foraminfera such as test abundance (foraminifera per gram), richness (Number of species), composition (total benthic foraminifera), calcareous / agglutinated ratio, (species, genera, family and suborder), various diversity indices especially fisher index, morphogroups including life habits and feeding strategies.

The deposition of Chari Foramation exposed at different domes of Kutch Mainland took place in shallow water, near shore environment with fluctuating shore-line in a tectonically unstable shelf ranging from mid to ouer shelf. However, the lower portion of the Jurassic succession of Kutch, namely Patcham Formation deposited in a calm, open marine environment with normal salinity condition in deeper shelf region. However, foraminiferal assemblages from more sections of different domes should by analysed using presently available techniques for palaeoecological analysis using froaminifera, for a more acurate and reliable interpretation of the depositional environment of the Jurassic rocks of Kutch.

FORAMINIFERAL AFFINITY AND PALAEOGEOGRAPHY

Jurassic foraminiferal palaeogeography of the Indian region including Kutch and Rajasthan is still controversial. Few available studies assign the Kutch Jurassic foraminiferal assemblages mainly to the Tethyan Realm, *viz*., Bhalla and Abbas (1976b, 1978), Bhalla and Talib (1991), Talib and Bhalla (2006b) Talib and Gaur (2008), Gaur and Talib (2009), Talib *et al*., (2012a). A few studies place this region in the Antiboreal Realm (Kalia and Chowdhury, 1983; Bhat *et al*., 2016; Talib *et al*., 2017a and Wasim *et al*., 2017), whereas Bhalla and Abbas (1976b) regarded the Jurassic foraminiferal assemblages of Kutch as endemic. The palaeogeographic studies carried out on the basis of ammonite fauna, identified three faunal realms during the Jurassic: Boreal, Pacific and Tethyan (Arkell, 1956). Hallam (1969) proposed only the Tethyan and Boreal realms as the Pacific Realm fauna is very close to Tethyan ones. Some authors who have studied the Kutch Jurassic macrofaunas found close affinity of this region with Salt Range and the Baluchistan regions of Pakistan, Arabia, Madagascar and East Africa (Rajnath 1942; Arkell 1956; Pascoe 1959; Teichert 1970; Jana *et al*., 2005). Arkell (1956) also suggested that an arm of the Tethys extending from near Iran to Madagascar through Baluchistan and the east coast of Africa also covered the Kutch and western Rajasthan regions of India. This arm divided the Gondwanaland in to eastern and western parts and faunas of the Ethiopian Province flourished in this Jurassic gulf. Later, other authors (Said and Barakat 1958; Teichert 1970; Bhalla and Abbas 1976) supported the interpretation of Arkell (1956).

There is no consensus between foraminiferal researchers regarding palaeogeographic affinity of the Jurassic foraminifera of Kutch, probably due to meagre data. The Jurassic foraminiferal assemblages of the Kutch and neighbouring Rajasthan contain species mostly reported from Europe and North America included in Boreal Realm and it appears that assigning them to the Tethyan Realm is inorrect. However, Talib and Gaur (2008) contested that although the majority of the Indian Jurassic foraminiferal species are similar to those of Europe and North America, there are sufficient diffrences in their frequency of occurrence and morphology to separate them from the Boreal forms.

In the Kutch and Rajasthan material, some typical Jurassic Tethyan foraminiferal species of *Gubkinella, Kurnubia, Pfenderina*, *Pseudolamarckina, Pseudomarssonella*, and *Ryadhella* are reported in small numbers by difrrent workers including Garg and Singh (1983), Kalia and Chowdhury (1983), Mandwal and Singh (1994), Garg and Jain (2012), Jain and Garg (2014). In the Kutch Basin, out of a total of 507 species reported so far, only 18 are typical Tethyan forms (3.55%) whereas in the Jaisalmer Basin 25 out of 149 species show Tethyan affinity. This was also observed by Kalia and Chowdhury (1983), Bhat *et al*., (2016) and Talib *et al*., (2017a) who suggested that these rare Tethyan species in the foraminiferal assemblages of Rajasthan and Kutch basins may be due to the mixing of the Antiboreal and the Tethyan elements in a transitionl border area between the two realms.

The concept of bipolarity as proposed by Strakhov (1962) for Late Jurassic belemnoids, suggests the development of similar fauna at the same latitudinal positions in northern and southern hemispheres which was supported by Gordon (1970). Later, Kalia and Chowdhury (1983) supported this concept of bipolarity for the Jurassic foraminifera of Rajasthan, India. The Jurassic foraminifera of Kutch and Rajasthan appear to support the concept of bipolarity and, accordingly, the foraminiferal assemblages of Kutch and Rajasthan may be assigned to a separate province of the Antiboreal Realm designated here as 'Indo-East African Province' situated near the southern margin of the Tethyan Realm and covered by a shallow gulf formed by southwestern arm of the Tethys. However, more data and detailed palabiogeographic analysis of Jurassic foraminifera of Kutch is required to arrive at a definite conclusion.

CONCLUSIONS

In view of the forgoing synthesized account, it is evident that the Middle - Late Jurassic rocks exposed in Kutch Mainland as well in nothern ridge yielded prolific foraminiferal assemblages which have been employed for various interpretations such as biostratigraphy, depositional environment, and palaeozoogeoraphy. These findings definitely helped to some extent in the understanding of the Jurassic rocks of the Kutch region of Gujrat State, India.

The Middle - Late Jurassic rocks exposed in different exposures of Kutch, yielded prolific foraminiferal assemblages comprising 507 species recovered from 10 sections. These included 41 species reported for the first time globally as well as 347 species for the first time in India whereas 119 are indeterminate species. The dominant foraminiferal species belong to the suborder Lagenina (272 species/55.74%), family Vaginulinidae (176 species/36.06%), and genus Lenticulina (40 species/7.89%). The assemblages represent both calcareous and agglutinated forms, dominated by the former. Calcareous hyaline species are dominant with 369 out of 507 and the Agglutinated/ Calcareous ratio is1: 2.7.

The Jurassic foraminiferal assemblages so far described from Kutch Mainland contain mostly long ranging species. However, a number of species have been identified which may be considered as marker for different stages of Middle and Late Jurassic. These include species restricted to single stage either globaly or in the Indian region as well species which are rather long ranging but considered by various authors as marker for different stages of the Middle and Late Jurassic. On the basis of these marker species, Patcham and Chari formations of the Kutch Jurassics are assigned Bathonain to Oxfordian age. The age suggested by the foraminiferal assemblages is in conformity with that indicated by the megafossils.

The foraminiferal assemblages are employed to interpret the palaeoecology and depositional environment of the enclosing sediment using several contemporary techniques and a shallow water, near shore, open marine environment from middle to outer shelf is interpreted for the Patcham and Chari formations of the Kutch Jurassics, with frequently fluctuating strandline where the salinity was normal and dissolved oxygen level normal to high.

Most of the earlier studies assign the Middle to Late Jurassic foraminiferal assemblages of Kutch and Rajasthan to the Tethyan Realm. However, recent studies assigned them to a separate province of the Antiboraeal Realm, an equivalent of the Boreal Realm in the southern hemisphere. The Jurassic foraminiferal assemblages of India and neighbouring regions appear to be occupying a distinct forambiogeographic province of the Antiboreal Realm, herein named as the Indo-East African Province, occupied by a shallow southwestern arm of the Tethys and located at the southern margin of the Tethyan Realm and appears to be transitional between the Tethyan and the Antiboreal realms.

Most of the Foraminiferal studies on Jurassic rocks of Kutch are devoted to systematics, followed by biostratigraphy, palaeoecology, and palaeobiogeography. More studies on these aspects as well as other additional aspects such as palaeoclimatic studies including isotopic analysis, are required for a thorough unserstanding of the Jurassic rocks of Kutch.

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