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Jurassic Foraminifera from Habo Dome, Kachchh, Gujarat

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***Abstract*: Foraminiferal assemblages covering 86 species are recorded from Jurassic rocks of Habo Dome, Kachchh out of which, 30 species are described for the first time from the Indian province and 52 for the first time from Habo Dome. Families Vaginulinidae and Lituodidae are dominating in the present assemblages. Preliminary interpretations related to age, depositional environment, and paleobiogeography are attempted. Based on various short-ranging species, the present foraminiferal assemblages suggest Bathonian to Oxfordian age for the studied sequence. Based on dominance of calcareous hyaline tests, genus *Lenticulina* and morphogroup J1, the sediments of Habo Dome are interpreted to have been placed in a shallow, open marine environment shifting between mid to outer shelf regions and having average salinity, average to high oxygen levels, and a relatively high sedimentation rate and nutrient influx.**

***Index Terms*: Jurassic, Foraminifera, Habo Dome, Kachchh, Age, Palaeoecology, Palaeobiogeography**

I. "INTRODUCTION"

Marine Jurassic rocks of the Kachchh area of Gujarat, western India, are well known for having diverse marine mega-invertebrate fossils and microfossils. About 2430m thick Mesozoic sediments are filled into the Kachchh basin (Panday *et al*., 2009) with great exposures of Jurassic rocks ranging in age from Middle Jurassic to Early Cretaceous (Bajocian to Tithonian) (Biswas, 1993; Panday and Dave, 1993; Fursich *et al*., 1994, 2001; Krishna *et al*., 1994, 1995, 1996a, b, c, 1998, 2000; Krishna and Ojha, 1996, 2000; Krishna, 2005, 2012; Krishna *et al.* 2009a, b, c, 2011; Rai and Jain, 2012, Panday *et al*.,2012a, b, 2013; Panday and Pathak, 2015). Various researchers have done comprehensive investigations of these sediments, mainly employing mega-invertebrate fossils, but relatively few publications are available on microfossils.

In view of the above, theaim of author is to carry out foraminiferal analysis of these sediments, and the current study is a preliminary account of the work carried out so far, mainly the occurrence of species for the first time in India and some generalized interpretations concerning age, depositional environment, and palaeobiogeography. A copious and well exposed succession of Jurassic rocks in Habo Dome near Dharang village (23º22'7.9" N, 69º50'59" E), about 40km northeast of Bhuj, Gujarat state, is selected for the current study as shown in Fig. 1. Previously, 65 species from the Habo Dome sequence have been recorded by Bhalla and Abbas (1978) and 59 species from Dharang Member of Habo Dome by Talib *et al*., (2016b). Surprisingly, Bhalla and Abbas (1978) did not record a single species of the genus *Epistomina* which is biostratigrpahically significant during the Jurassic. However, Talib *et al*., (2016b) found seven species of this genus.

A detailed systematic and taxonomic account of the recovered assemblages and interpretations drawn on their basis is in progress and will be published in due course.

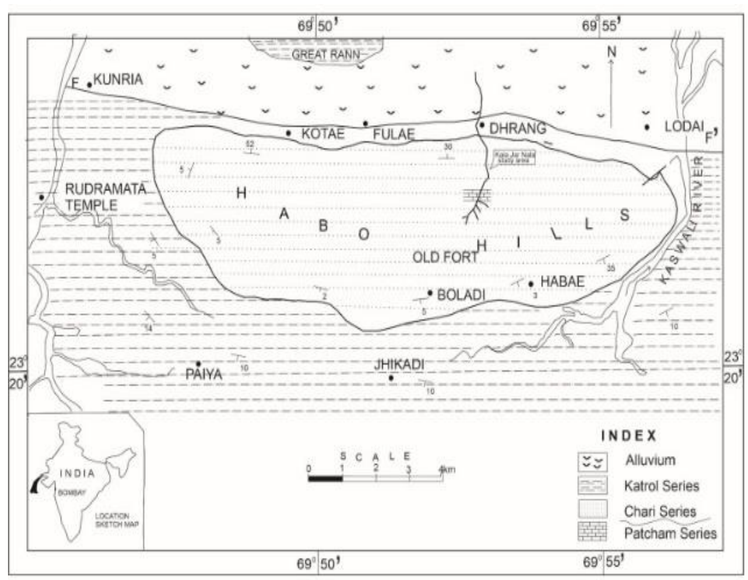


Fig 1. Geological Map of Habo Dome (after Bhalla and Abbas, 1978)

II. "Geology And Stratigraphy"

The Kachchh Basin is filled with about 1950m thick pile of well-developed Jurassic sediments (Bhalla, 1983). They are exposed inthree anticlinal ridges that run east-west and a sizeable detached outcrop in the east, close to Wagad. The central ridge, which is fractured into several domes and exposed with quaquaversal dipping Jurassic outcrops, is the most notable. One of the large domes of this ridge is the Habo Dome. In general, four formations are identified in the Jurassic rocks of Kachchh, spanning in age from Middle Jurassic to Early Cretaceous (Bajocian to Aptian/Early Albian) (Krishna *et al.*,1994; Panday *et al.*, 2012; Panday and Pathak, 2015) in ascending order of Patcham, Chari, Katrol, and Umia. Patcham, Chari, and Katrol formations are seen in the Habo Dome, ranging from Bajocian to Early Tithonian (Panday *et al.*, 2012; Panday and Pathak, 2015).

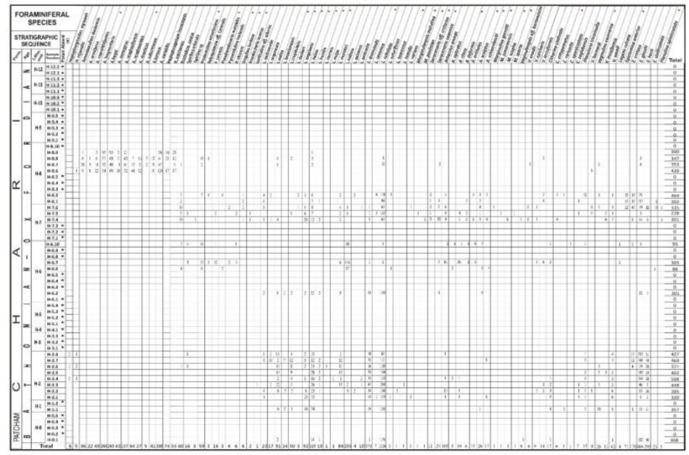
III. "Methodology"

A total of 62 samples are collected along Kala Jar Nala in the Habo Dome, near Dharang village, which covers Patcham, Chari,and Katrol formations.Approximately 300-400 gm of field samples were crushed and boiled for three to four hours with washing soda, then sieved with 30, 60, and 120 µm mesh and dried. From the dried material, the microfauna is picked out, followed by the arrangement on microfaunal slides for identification. The genera and species are identified using the generic classification of Loeblich and Tappan (1988) and Ellis & Messina catalogues, respectively. The SEM images are captured by JEOL - JSM-6510LV Scanning Electron Microscope at University Sophisticated Instruments Facility (USIF), Aligarh Muslim University, Aligarh.

IV. "Foraminiferal Composition"

The studied section contains the foraminiferal assemblages having 86 species from which 30 species are reported for the first time from India (Fig. 2, Plate I) and 52 first times from Habo Dome. The foraminiferal assemblages belong to six suborders. Out of these, Lagenina contains16 genera and 61species constituting 70.93% of the total species, Textulariina with three genera and 16 species, constituting 18.60%, Robertinina with one genus and five species constituting 5.81%, Sprillinina with one genus and two species constituting 2.32%, Involutina and Rotaliina both having one genus and one species and comprising 1.16%.

The present foraminiferal assemblages include 12 families. Out of these, Vaginulinidae is dominant, having 52 species belonging to 9genera (60.46%). This is followed by family Lituolidae having 12 species belonging to one genus (13.95%), Nodosariidae having 5 species of four genera (5.81%), Epistominidae having 5 species belonging to one genus (5.81%); Spirillinidae, Robuloididae, Haplophragmoidadae, and Haplophragmidae all having 2 species of one genus (2.32% each). Ichthyolariidae, Lagenidae, Planulinidae, and Involutinidae all having one genus and one species (1.16% each). Calcareous species are dominant with agglutinated vs. calcareous ratio of 1:4.37.



*Species reported for the first time from India

Fig2. Distribution of foraminiferal species in the Jurassic sequence of Habo Dome, Kachchh.

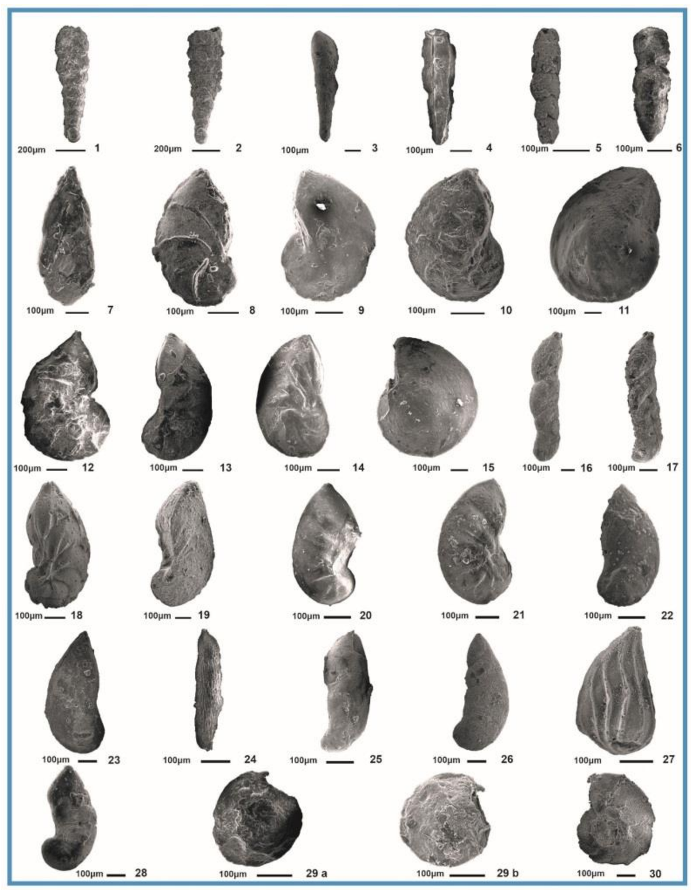


Plate I

Plate I fig. 1. *Ammobaculites fragmentaria* (Cushman, 1927); 2.*A. rhaeticus*(Kristan-Tollman); 3. *Prodentalina vetustissima* (d'Orbigny, 1850); 4. *Pyramidulina obscura* (Reuss,1846); 5. *Pseudonodosaria mutabilis* (Resus, 1863); 6. *Lingulina lordosa* (Loeblich and Tappan 1950); 7. *Frondicularia inversa* (Reuss, 1844); 8. *Lenticulina crepidula* (Fichtel& Moll, 1803); 9. *L. dunkeri* (Reuss, 1863); 10. *L. exgaleata* (Dieni, 1985); 11. *L. helios* (Terquem, 1870a); 12. *L. inermis* (Terquem, 1862); 13. *L. major* (Bomemann, 1854); 14. *L. saxonica* (Bartenstein and Brand, 1951); 15. *L. tumida* (Mjatliuk, 1961); 16. *Marginulinopsis matutina* (d'Orbigny, 1850); 17. *M. pauliniae* (Terquem, 1866); 18. *Saracenaria saxonica* (Bartenstein and Brand,1951); 19. *Saracenaria aff. S. cretacea*(Dailey, 1970); 20. *Astacolus deformis* (Bornemann, 1854); 21. *A. eritheles* (Leoblich and Tappan, 1950); 22. *A. scalpatus* (Franke, 1936); 23. *A. schloenbachi* (Reuss, 1863); 24. *Marginulina garretti* (Cushman and Ellisor, 1945); 25. *M. scapha* (Lalicker, 1950); 26. *M. sporta* (Lalicker, 1950); 27. *Citharia raricosta* (Fursenko and Polenova, 1950); 28. *Vaginulina excentrica* (Cornuel 1848); 29a. *Epistomina anterior* (Bartenstein and Brand 1951), ventral view; 29b. *E. anterior* dorsal view; 30. *Planulina spissicostata* (Cushman, 1938).

V. "Foraminiferal Assemblages Dating"

Due to ordinarily long ranges, Jurassic foraminifera is not suitable for precise age determination as compared to ammonites.Still, a number of researchers have identified many species which have been used for fairly accurate age determination of these rocks. A significant number of short-ranging species recovered from the present assemblages are used for dating these sediments.

The present foraminiferal assemblages of the Habo Dome comprise six species which have a globally long-time span but in India represent Bathonian, viz., *Lenticulina quenstedti. muensteri, L. subalata, Citharina clathrata, C. sparsicostata, and Planularia tricarinella. Lenticulina quenstedti, L. subalata, Citharina clathrata, Planularia tricarinella* are restricted to Bathonian of England (Coleman, 1981). *Lenticulina muensteri, L. subalata, and L. quenstedti* are restricted to Bathonian of Egypt (Shahin, 2000). *L. subalata* is regarded as typical of Bathonian in Kachchh by Panday and Dave (1993), whereas *Citharina sparsicostata* is restricted, globally as well as regionally in Kachchh, to Bathonian (Bhalla *et al*., 2019).

A total of 11 species of the present assemblages, viz., *Lenticulina audax, L. brueckmanni, L. nodosa. polonica, L. tumida, Astacolus anceps, A. clava, Marginulinopsis jumaraensis, Marginulina scapha, Vaginulinopsis aff. bartensteini, and Vaginulinopsis enodis* represent Callovian. Out of these, *Lenticulina polonica* occurs in Callovian of Germany and Poland (Bartenstein, 2000), and Kachchh, India (Bhalla *et al*., 2019 India), *L. tumida* is restricted to Callovian of Hungry (Gorog*et al*., 2012), *A. clava* occurs in Callovian of Poland (Wisniowski, 1890) and Kachchh, India (Talib *et al*., 2016b). *Vaginulinopsis bartensteini* is restricted to Callovian of Egypt (Said and Barakat, 1958), and Talib *et al*., (2016b) have shown its global occurrence in Callovian, including Kachchh, India. *Lenticulina brueckmanni* and *M. scapha* are restricted to Callovian of Rajasthan, India (Jain and Garg, 2014*). Lenticulina audax, L. nodosa, Astacolus anceps, Vaginulinopsis enodis, and Marginulina jumaraensis* are restricted to Callovian of Kachchh, India (Bhalla *et al*., 2019; Talib *et al*., 2016b).

Six species, viz, *Ammobaculites reophaciformis, Lenticulina major, Astacolus aphrastus, Vaginulinopsis epicharis, Citharina entypomatus*, and *Vaginulina barnardi* are globally restricted to Oxfordian. Out of these *A. reophaciformis* occurs in Oxfordian of England (Gordon, 1965) and Kachchh, India (Bhalla and Talib, 1991), *L. major* in Gottingen, Germany (Bornemann, 1854), *A. aphrastus* in South Dakota, USA (Leoblich and Tappan, 1950) and Kachchh, India (Wasim *et al*., 2020), *V. epicharis* in South Dakota, USA (Leoblich and Tappan, 1950) and Kachchh, India (Talib *et al*., 2014),*C. entypomatus* in South Dakota, USA (Leoblich and Tappan, 1950) and Kachchh, India (Talib *et al*., 2012b), and *V. barnardi* in England (Gordon, 1965) and Kachchh, India (Talib *et al*., 2016b).

Eight species of the present assemblages, viz., *Haplophragmoides agrawali, H. rajnathi, Ammobaculites alaskensis, A. hagni, Astacolus eritheles, Citharina zaglobensis, Epistomina cretosa*, and *E. Stellicostata* are restricted to Callovian to Oxfordian strata. Out of these, *H. agrawali and H. rajnathi*, are restricted to Callovian to Oxfordian of Kachchh, India (Bhalla and Abbas, 1978), *A. eritheles* to Kachchh, India (Bhalla and Talib, 1991), *Epistomina cretosa* to Kachchh, India (Talib *et al*., 2012a); and *Ammobaculites alaskensis, Ammobaculites hagni*, and *E. Stellicostata* to Kachchh, India (Talib *et al*., 2012b). *Ammobaculites hagni* is globally restricted to Callovian to Oxfordian, and *C. zaglobensis* occurs in Callovian to Oxfordian of Kachchh, India (Talib *et al*., 2016b).

Two species, viz., *Epistomina ghoshi* and *Lenticulina suturifusus* are restricted to Bathonian to Callovian of Kachchh, India (Talib *et al*., 2016b), whereas one species, Vaginulina woodi, ranges from Bathonian to Oxfordian of Kachchh, India (Wasim *et al*., 2021).

In view of the above discussions, it seems reasonable to assign a Bathonian to Oxfordian age to the Patcham and Chari formations exposed at Habo Dome, Kachchh. Earlier, Bhalla and Abbas (1978) indicated a Callovian to Oxfordian age to these rocks on the basis of foraminifera. Black Limestone, which is the basal lithounit of Habo Dome sequence, has been assigned a Bathonian age by Talib *etal*., (2016a) on foraminiferal evidence.

Although ammonites have not been used to date the entire Jurassic rocks exposed at Habo Dome,however, some scanty and indirect evidence based on ammonites indicates an upper Bathonian to Lower Oxfordian age for these sediments. The top of the Raimalro Member, dated as upper Bathonian, is lithostratigraphically correlated with Black Limestone, the lowermost lithounit exposed in Habo Dome (Calloman, 1993). Furthermore, in outcrops near Rudra Mata in the western part of Habo Dome, a thin oolitic sandstone layer covering the Dhosa Conglomerate Bed contains an ammonite fauna of Early Oxfordian age (Alberti *et al*., 2011). Dhosa Oolite is the uppermost lithounit of the Chari Formation. Kanjilal (1978),based on megafossil, including ammonites has indicated a Bathonian to Oxfordian age for the Patcham and Chari sequence exposed in Habo Dome. The current age indicated by the foraminiferal assemblages is in conformity with the majority of the studies based on micro- as well as megafossils.

VI. "PALAEOECOLOGICAL SIGNIFICANCE"

Since foraminifera has a high evolutionary rate and sensitivity to environmental variation with time, they can be a reliable indicator of various marine ecosystems. These microorganisms have established themselves as consistent tools to understand ancient environments and have been used extensively to examine Jurassic paleoenvironments worldwide (Barnard and Shipp, 1981; Bhalla and Abbas, 1984; Bhalla and Talib, 1991; Gebhardt and Richner, 1998; Talib and Gaur, 2005; Gaur and Talib, 2009; Talib *et al*., 2012a, b; Talib*et al*., 2014; Bhat *et al*., 2016, Talib *et al*., 2016 a, b; Wasim *et al*., 2017; Farahani *et al*., 2018; Reolid *et al*., 2019 a, b; Malik *et al*., 2020; Wasim *et al*., 2020, 2021; Kaminski *et al*., 2020).

Different proxies of benthic foraminiferal assemblages of Habo Dome, such as dominant taxa, test composition (Agglutinated/Calcareous ratio), and morpho group analysis of the foraminiferal assemblages, have been used for paleoenvironmental analysis.

The dominance of suborder Lagenina and family Vaginulinidae in the current foraminiferal assemblages suggest shallow water open marine environmental condition with normal salinity (Canales and Henriques, 2008; Gaur and Talib, 2009; Talib *et al*., 2012a, b; Talib *et al*., 2014; Bhat *et al*., 2016; Talib *et al*., 2016a, b; Wasim *et al*., 2017; Farahani *et al*., 2018; Reolid *et al*., 2019 a, b). The dominance of calcareous species in almost all the samples signifies a shallow open marine environment above the CCD with average salinity and well-oxygenated water (Barnard *et al*., 1981; Valchev, 2003; Ghoorchaei *et al*., 2012; Smolen, 2012; Bhat *et al*., 2016; Talib *et al*., 2016a, b; Wasim *et al*., 2017; Farahani *et al*., 2018; Reolid *et al*., 2019 a, b;Kaminski *et al*., 2020; Wasim *et al*., 2020). The porcelaneous test is absent in the present assemblages, which rejects closeness to the inner shelf, for porcelaneous tests except for a few genera such as Pyrgo, show inner shelf environment (Koutsoukos *et al*., 1990;Valchev, 2003; Smolen, 2012).

Genus *Lenticulina* is dominant in the present assemblages, which recommends open sea, deeper marine shelf environment, and an extreme degree of dissolved oxygen (Jones and Charnock, 1985;Bernhard, 1986; Koutsoukos *et al*., 1990; Nagy, 1992; Tyszka, 1994; Szydlo, 2004; Canales and Henriques, 2008; Reolid *et al*., 2008a, b, 2010, 2012;Nagy *et al*., 2009; Smolen, 2012; Bhat *et al*., 2016; Talib *et al*., 2016a, b; Wasim *et al*., 2017, Wasim *et al*., 2021). Genera such as *Redmondoides*, *Nautiloculina*, *Quinqueloculina*, and *Triloculina* are absent in the present assemblages, which arerelated to shallower shelf surroundings also help in interpreting a deeper shelf location for the current assemblages (Reolid *et al*., 2008a, b; Malik *et al*., 2020).

Seven morphogroups, viz., C2, D, G, H, J1, J2, and K (Reolid *et al*., 2008) occurs in the present foraminiferal assemblages, but J1 is dominant, having elongated uniserial test form and comprising of genera such as *Prodentalina*, *Falsopalmula*, *Pseudonodosaria*, *Pyramidulina*, *Lingulina*, *Marginulinopsis*, *Marginulina*, and *Lagena*. Supremacy of J1 indicates a shallow infaunal lifestyle with an abundance of active deposit-feeding herbivores and bacterial scavengers, representing an open marine shelf environment with average oxygen condition, average salinity and a relatively high sedimentation rate, and high nutrient influx (Farhani*et al*., 2018; Wasim *et al*., 2021)

From the above deliberations, it may be concluded that general deposition of the Jhurio Dome sediments at Habo Dome, Kachchh took place in open marine deeper shelf region, mainly mid to outer shelf with average salinity, normal to high oxygen levels, and relatively high sedimentation rate as well as nutrient influx.

VII. "PALEOBIOGEOGRAPHIC AFFINITY"

The Jurassic foraminiferal paleobiogeography of western India, Kachchh, is debatable, possibly because of the insufficient foraminiferal data for this period in India and its attached areas. The foraminiferal assemblages of Kachchh display some affinity with the Jurassic foraminiferal assemblages of the adjoining, the so-called Tethyan regions of Saudi Arabia, Egypt, Iran, Afghanistan, Ethiopia, and Eastern Mediterranean as well as various other parts of the world, viz., Europe, (U.K, Spain, Portugal, Germany, Russia) and North America, blanketed in the Boreal Realm. An effort is made right here to set up the palaeobiogeographic affinity of the Middle to Late Jurassic foraminiferal assemblages of the Habo Dome, Kachchh, and to reconstruct the paleogeography of this region for the duration of the Middle to Upper Jurassic.

Various researchers have assigned a Tethyan affinity for the Middle to Upper Jurassic foraminiferal assemblages of Kachchh (Bhalla and Abbas, 1976, 1978; Bhalla and Talib, 1991; Talib and Bhalla, 2006b; Talib and Gaur, 2008). Kalia and Chowdhury (1983), however, assigned the Jurassic foraminifera of Rajasthan, western India, to the Antiboreal Realm after the notion of bipolarity proposed by Strakhov (1962) for bivalves and later by Gordon (1970) for Jurassic foraminifera.

The Habo Dome foraminiferal assemblages consist of mostly species recognized from the Boreal Realm, and an overwhelming number of the current species from Kachchh and Rajasthan is comparable to the European and North American assemblages. This may be due to the development of a fauna similar to the Boreal Realm at nearly the same but opposite latitudes in the southern hemisphere in the Antiboreal Realm, following the concept of bipolarity.

In the Kachchh and Jaisalmer basins placed in Gujarat and Rajasthan states of India, some traditional Jurassic Tethyan foraminiferal species of*Gubkinella*, *Kurnubia*, *Pfenderina*, *Pseudolamarckina*, *Pseudomarssonella*, and *Ryadhella* are recorded in small proportions by a number of authors (Bhat *et* *al*., 2016). Bhat *et al*., (2016) observed that in the Kachchh Basin, out of a whole of 466 species recorded so far, only 59 have Tethyan affinity (12.66%), whereas, in the Jaisalmer Basin, 32 such species are found out of a whole of 216 (14.81%). However, as suggested by Kalia and Chowdhury (1983), small percentages of foraminifera of Tethyan affinity in the foraminiferal assemblages of Jaisalmer and Kachchh basins may be due to a mixing of the Antiboreal and the Tethyan speciesthat is obvious in transition zones.

In view of the above, the foraminiferal assemblages of the Habo Dome, as well as other Middle and Late Jurassic foraminiferal assemblages from Kachchh and Rajasthan, may be assigned to the Antiboreal Realm, which is the southern hemisphere's counterpart of the Boreal Realm. This can be explained by the fact that during the Middle to Late Jurassic interval, the Indian subcontinent was located almost on the equalbut the opposite latitudinal extent of the Boreal Realm in the southern hemisphere and, therefore, a foraminiferal fauna comparable to the Antiboreal Realm flourished. The Jurassic foraminiferal assemblages of western India, including Kachchh and Rajasthan,as well as neighbouring countries, were occupying a distinct foraminiferal biogeographic domain of the Antiboreal Realm, the Indo-East African Domain during the Middle to Late Jurassic interval.

"CONCLUSION"

Rich foraminiferal assemblages of 86 species and 7754 individuals were discovered in Middle to Late Jurassic strata exposed at Habo Dome,Kachchh in western Gujarat, India. These include 30 species documented for the first time from the Indian Peninsula. The present assemblages are dominated by calcareous hyaline species with an Agglutinated/Calcareous proportion of 1:4.37. The most dominant suborder and family are Lagenina and Vaginulinidae, respectively. Genus *Lenticulina* and species *Lenticulina subalata* are predominant.

The enormous majority of the species have a relatively long-time span. However, based on a significant number of short-ranging species which frequently occur globally as well as in the Indian region, a Bathonian to Oxfordian age is indicated for Jurassic rocks exposed at Habo dome, Kachchh. Based on the supremacy of the suborder Lagenina, family Vaginulinidae, calcareous hyaline test composition, the genus Lenticulina, and J1 morphogroup an open marine shelf environment, with average salinity, average to high oxygen levels, a usually high sedimentation rate, and high nutrients availability are proposed throughout the deposition of these sediments. The foraminiferal assemblages are allocated to the Indo-East African Domain of the Antiboreal Realm.

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