Foraminiferal composition and age of the Chari Formation, Jumara Dome, Kutch

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The Chari Formation exposed at Jumara Dome, western Kutch yielded a prolific foraminiferal assemblage comprising 51 species, including one new species. Sixteen species are reported for the first time from the Indian region. The foraminiferal assemblage, dominated by families Vaginulinidae and Nodosariidae, is employed to date these sediments. The assemblage includes mostly long-ranging species. However, on the basis of a few short-ranging species restricted within the Callovian–Oxfordian and some species though long-ranging but mostly occurring in the Callovian–Oxfordian sequences of different parts of the world, a Callovian to Oxfordian age is assigned to the studied sequence. A Callovian age is favoured as the lower limit of the Chari Formation of the Kutch Jurassic on the basis of some representative Callovian foraminiferal species occurring in the lowermost lithounit of the Chari Formation in the Jumara Dome. An attempt is made to delineate the Callovian–Oxfordian boundary in the studied sequence on the basis of some fairly restricted and characteristic Callovian and Oxfordian foraminiferal species.

Keywords: Age, Chari Formation, Callovian–Oxfordian boundary, composition, foraminiferal species.

The current boost to petroleum exploration activities in the country provided impetus to geological research in the Kutch region during the past few years. In view of this, a comprehensive foraminiferal study of the Jurassic rocks of Kutch was undertaken in order to interpret the biostratigraphy, palaeoenvironment, palaeogeography and tectonic history of this basin. The present study reports the foraminiferal composition and its application in dating the well-exposed Chari Formation in the Jumara Dome, western Kutch (Figure 1).

Geology of the area

Jurassic rocks of Kutch are exposed in three nearly east-west trending anticlinal ridges. Of these, the middle ridge is the most conspicuous and broken up into a number of domal outcrops having quaquaversal dips. The Jumara Dome is one of the prominent domes situated on the western portion of the middle ridge, located nearly 80 km northwest of Bhuj, the district headquarters of the Kutch region. The Jumara area has been famous in the Jurassic stratigraphy of Kutch for its abundant megafossils and good exposures. The most widely accepted classification of the Jurassic rocks of Kutch divides these rocks into Patcham, Chari, Katrol and Umia formations, in ascending order. However, in the Jumara Dome only the first three formations are exposed. Of all the exposures of the Jurassic rocks of Kutch, the Chari Formation is the thickest and best developed in this dome, exposing a total thick-

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Figure 1. Geological map of Kutch showing Jumara Dome (after Fürsich et al.).
ness of about 245 m. In fact, the Julbara Dome is the type area of Julbara Formation, an alternate name for the Chari Formation, coined by Biswas in a later proposed lithostratigraphic classification of the Jurassic rocks of Kutch.

In the Julbara Dome, good exposures of the Chari Formation are developed in two nala cuttings, locally known as Teen-phuar and Barh nala, situated on the northern and northwestern flanks respectively, of the Julbara Dome. These sections were selected for the purpose of the present study. The Chari Formation of the Julbara Dome is mainly composed of carbonate rocks with abundant megafossils. A small basic intrusion in the form of a dolerite sill is exposed in the Barh nala section. The stratigraphic sequence has been worked out mainly on lithological basis, which comprises six lithounits. These are numbered from 1 to 6 and prefixed with the letters JM to denote the Julbara area.

Nineteen samples were collected from the six lithounits of the Chari Formation exposed in Teen-phuar and Barh nala sections. The samples were collected mainly on the basis of lithological variations and not at regular intervals. Routine micropalaeontological procedures were employed to retrieve the foraminiferal specimens.

**Foraminiferal composition**

The Chari Formation of the Julbara Dome yielded a fairly rich foraminiferal assemblage comprising 51 species, including one new species, viz. Flabellammina bharatica (Figure 2). Among these, the following 16 species have been reported for the first time from the Kutch region: Thurammina diforans Eisenack, Reophax tener Siebold and Siebold, Ammobaculites fermoic Ziegler, Triplasia emslandensis Bartenstein and Brand, Laevinalvina aff. L. sarthacensis (Schwager), Nodosaria cylindracea Costa, Frondicularia ignaria Terquem, F. nosodaria Terquem, Marginulopsis instabilis (Terquem), Astacolus beiurana (Gümbel), A. filosa (Terquem), Vaginulopsis aff. V. stephensoni (Cushman), Vaginulina ectypa (Loeblich and Tappan), Vaginulina inspissata Loeblich and Tappan, Lagena sulcata (Walker and Jacob) and Ramulina apheilolocula (Tappan).

Majority of the foraminiferal species belong to the family Vaginulinidae, constituting 43.13% of the total number of species in the assemblage (Figure 3). This is followed by families Nodosariidae (21.56%), Litulidae (11.76%), Trocholidae (5.88%), Lageneridae (3.32%) and 1.96% each of families Saccamminidae, Ammodiscidae, Hormosinidae, Haplophragmoididae, Spirillidae, Poly morphinidae and Epistominidae.

The Julbara foraminiferal assemblage also includes four indeterminate species, one each belonging to Ammodiscus, Trocholina, Lagena and Lenticulina, which do not bear resemblance to any known species of these genera. These are probably new species, but more specimens are required to assign them trivial names.

![Figure 2. Frequency distribution of foraminifera in the Chari Formation, Julbara Dome, Kutch.](image-url)
Age of the foraminiferal assemblage

The use of foraminifera in dating sediments, especially those of Cretaceous and Cenozoic, is well established. This is primarily due to the presence of a good number of planktonic forms during these geological time-spans, providing marker taxa useful for dating and correlation. During the Jurassic Period, foraminifers have proved their biostratigraphic value only in the Lower Jurassic rocks, the degree of resolution sometimes matching that of ammonites. However, Middle and Upper Jurassic foraminifera have not proved themselves reliable enough for precise age determination, particularly in the Indian region. This may be due to the fact that most of the Middle and Upper Jurassic foraminiferal species from the Indian region are rather long-ranging and truly marker benthonic and planktonic species are either rare or absent. Gradstein, and later Pandey and Dave, however, recommended the use of species of Garantella, Reinholdella and reticulate Epistomina in Jurassic biostratigraphy. Williamson and Stami also opined that species of Epistomina are useful biostratigraphic markers, at least up to stage level. However, only a single species of Epistomina could be recovered from the Jumara Dome sequence.

The age fixation of the Middle to Upper Jurassic sediments becomes further complicated because of the usual dominance of vaginulids and nodosariids during this time. Species belonging to these families are fairly long-ranging and exhibit a high degree of inter as well as intraspecific variation. Such species are hardly of any value in age determination, unless their morphologic variation with time is thoroughly investigated and established. These facts also apply to the present foraminiferal assemblage. However, an attempt is made here to date these sediments on the basis of some fairly short-ranging species present in the Jumara Dome foraminiferal assemblage.

The age of the Chari Formation has been debated over for quite a long time. A Callovian to Oxfordian age was suggested by Waagen and the same was supported by a large number of later workers. Spath assigned a Bathonian age to the Macrocephalus beds, the lowermost zone of the Chari Formation. However, Agrawal and Arkell did not favour the assigning of Bathonian age to the Macrocephalus beds. Some researchers favoured a Bathonian to Oxfordian age for the Chari Formation. However, Khosla and Jakhar considered Callovian-Oxfordian age for the Chari Formation of Jumara Dome. This shows that though there is a general agreement on the upper age limit of the Chari Formation, the age of the lower limit or in other words, the age of the Macrocephalus beds remains controversial. As mentioned earlier, the Chari Formation of Jumara Dome is the thickest and most well developed in the entire Kutch region and Jumara is one of the only three domes where the lower part of the formation is exposed. Therefore, it is probably the most suitable area for investigating the lower age limit of the Chari Formation.

The Jumara foraminiferal assemblage includes certain well-known species reported from Bajocian, Bathonian, Callovian, Oxfordian, Kimmeridgian and Tithonian stages in different parts of the world as well as a few species originally recorded from Cretaceous, but later found to be extending down the Jurassic (Figure 4).

Figure 4 reveals that Lenticulina subalata and L. tricarinella are the longest-ranging species in the present assemblage, extending from Lower Jurassic to Cretaceous. A few species having long ranges within the Jurassic include Spirillina polygrata and Lenticulina varians, which extend from Lias to Maln, whereas Astacolus pauperatus and Citharina clotharata are found to be confined to Lower and Middle Jurassic sediments of various parts of the world.

A small percentage of Jumara species have their vertical ranges within the Middle and Upper Jurassic. It includes Vaginulina misensis originally reported from Kim-
meridgian of Egypt\textsuperscript{17}, but later found in Bajocian of Iran\textsuperscript{48} and Callovian of Rajasthan\textsuperscript{15}. \textit{Lenticulina quenstedti}, a well-known Jurassic species exhibits a continuous range from Bajocian to Kimmeridgian; \textit{Tristix oolithica}, though ranging from Callovian to Tithonian, has mostly been recorded from Oxfordian of North America and England\textsuperscript{49,50} and \textit{Asterolites aeneus} has been reported from Bajocian of Iran\textsuperscript{46}, Bathonian of England\textsuperscript{45}, Callovian of Scotland\textsuperscript{50} and also from the Callovian-Oxfordian strata of different parts of the Kutch region\textsuperscript{1,3,16,18}. Kalantari\textsuperscript{58} recorded the frequent occurrence of \textit{Ramulinina aphetolocula} in the Bajocian sediments of northeast Iran, while it was first described from Pliensbachian of Alaska\textsuperscript{51}.

\textit{Epistominia mosquensis} present in the Jamara foraminiferal assemblage is considered as a significant species for dating the Jurassic sediments. It has been recorded from the Middle and Upper Jurassic sediments of Europe, Canada, Portugal, Madagascar and Iran, as well as the Kutch region.

A fairly good number of foraminiferal species having a restricted vertical range in Callovian to Oxfordian sediments of many parts of the world are present in our assemblage. Notable amongst them are \textit{Citharinella rhomboidea} and \textit{Asterolites aphanus}, which have been originally described from Oxfordian of USA\textsuperscript{52}. However, these species have also been recorded from Callovian–Oxfordian of Habo and Jhurio domes of Kutch\textsuperscript{13,16}, as well as from Callovian of Rajasthan\textsuperscript{15}. \textit{Ammobaculites gowdai}, \textit{Trocholina conosimilis}, \textit{Laevidentalina gibleri}, \textit{Frondiculina kutchensis} and \textit{Vaginulina woodi} are all known to occur in the Callovian–Oxfordian of Kutch\textsuperscript{7,13,16,31}.

Kalia and Chowdhury\textsuperscript{15} reported the occurrence of \textit{Trocholina} cf. \textit{T. conosimilis} and \textit{Laevidentalina glibleri} from the Callovian of Rajasthan, while the latter has also been reported from the Callovian of Scotland\textsuperscript{50} as well as Oxfordian of England\textsuperscript{12} and Germany\textsuperscript{53}. However, \textit{Citharinella rhomboidea} and \textit{Laevidentalina glibleri} have also been reported from Middle Toarcian to Lower Bajocian and Middle Toarcian sediments respectively, of Canada\textsuperscript{54}, but these two species are found to occur commonly during Callovian-Oxfordian interval in other parts of the globe. \textit{V. woodi} and \textit{T. conosimilis} have also been reported from Bathonian and Bajocian to Tithonian rocks of Kutch respectively\textsuperscript{18}, but they mostly occur in Callovian–Oxfordian sediments.

Three fairly short-ranging species encountered in the Jamara assemblage include \textit{Trocholina nodulosa} reported from Oxfordian of South Germany\textsuperscript{55} and northeast Iran\textsuperscript{48}, \textit{Vaginulina ectypa} described from Oxfordian of USA\textsuperscript{57}, and \textit{Marginalina bhatiae} from Callovian of Jhurio Dome, Kutch\textsuperscript{10}.

The present assemblage also includes some foraminifer species originally described from the Cretaceous sediments, but are also known to occur in the upper part of the Middle Jurassic or in Upper Jurassic. \textit{Hemirobula curvatura} has earlier been recorded from the Cretaceous sediments of different regions of the world\textsuperscript{48,56–59}, but this species also occurs in the Callovian–Oxfordian of Jhurio Dome, Kutch\textsuperscript{10}, \textit{Nodosaria aff. N. marginata}, originally described from the Cretaceous of Germany\textsuperscript{50}, has been recorded from the Callovian and Oxfordian of Habo Dome, Kutch\textsuperscript{13}. \textit{Ammobaculites roephacioides}, first
described from Lower Cretaceous of Germany, also occurs in the Callovian to Oxfordian sediments of Kutch, and Ammomarginulina cragini, which was first reported from the Lower Cretaceous of USA, has also been found in the Oxfordian of Canada and Kutch. Triplaia emslndensis is the single element of Cretaceous in the Jumara material, which has probably not been so far reported from any Jurassic sequence. This species is invariably restricted to Hauterivian of Europe and Asia.

From the above discussion, it is apparent that truly marker species are rare in the foraminiferal assemblage recovered from the Chari Formation of the Jumara Dome, Kutch. However, the assemblage includes an appreciable number of fairly short-ranging species which are known to be confined to or representative of Callovian to Oxfordian strata in different parts of the globe. On this basis, a Callovian to Oxfordian age is being suggested for the studied sequence exposed at the Jumara Dome, Kutch. The occurrence of A. anceps, A. pauperatus and E. mosquensis, which are considered as representative foraminifera of Callovian and the absence of any characteristic Bathonian foraminifera, in the lowermost lithounit JM-1 of the Chari Formation, favour Callovian as the lower age limit of the Chari Formation.

**Callovian–Oxfordian boundary**

Although considerable work has been carried out on the megafossils and biostratigraphy of the Jumara area, no attempt has yet been made to mark the Callovian–Oxfordian boundary either on mega or microfaunal evidences. An attempt in this direction is made here on foraminiferal evidences. Earlier, Bhalla and Talib, and Maniwal and Singh attempted to mark the Callovian–Oxfordian boundary in the Jhuri Dome, Kutch, on the basis of foraminiferal evidence.

As stated earlier, the Jumara Dome foraminiferal assemblage comprises mostly long-ranging species. Marker species, vital for making the finer subdivisions of the studied sequence, are rare. However, the present assemblage contains certain species which have fairly limited occurrence either in Callovian or Oxfordian sediments of different parts of the world. A few other species, though quite long-ranging, do not extend beyond Callovian. These foraminiferal species are employed in demarking the boundary between the Callovian and Oxfordian strata in the Jumara sequence.

The frequency distribution chart (Figure 2) reveals that lithounits JM-1 to JM-5 are characterized by the presence of A. anceps, A. pauperatus, C. clathrata, M. bhatiai and E. mosquensis, which do not extend beyond lithounit JM-5. These include species which are restricted to Callovian or are rather long-ranging, but do not extend beyond Callovian, and species which commence from Callovian and extend beyond it, but are regarded as representative of Callovian by various authors (Figure 4). Though A. anceps ranges from Bajocian to Oxfordian, Pandey and Dave regarded it as a zonal marker of the Proteinina diffugiformis – Astacolus anceps Zone of Upper Callovian age in Kutch. This species extends up to lithounit JM-5 in the present sequence. A. pauperatus and C. clathrata range from Hettangian to Callovian and have not been so far recorded in sediments younger than Callovian. In the present sequence, A. pauperatus is confined only to lithounit JM-1, whereas C. clathrata extends from JM-1 to JM-5. The solitary occurrence of M. bhatiai is from the Callovian, Jhuri Dome, Kutch and this species is restricted to lithounits JM-1 and JM-2 of the present sequence.

A number of foraminiferalists have noted that E. mosquensis, though ranging from Callovian to Tithonian, frequently occurs in Callovian strata. Bartenstein et al. assigned a Callovian age to E. mosquensis in Germany. According to Kalantari, the first occurrence of this species marks the base of Callovian strata and it is a representative of Callovian in Iran. Pandey and Dave considered E. mosquensis as an important species of Callovian in Kutch. In the present section, E. mosquensis appears in lithounit JM-1 and extends up to lithounit JM-5.

Considering the vertical ranges of the above-mentioned species in the studied sequence of the Jumara Dome, it
may be inferred that lithounits JM-1 to JM-5 belong to Callovian.

Lithounit JM-6 of the Jamara sequence includes a few short-ranging species which have mostly been recorded from Oxfordian strata in different regions of the world. These are *T. nodulosa* and *V. ectypa*. *T. nodulosa* was first described from Oxfordian of Germany.$^{53}$ It also occurs in Oxfordian sediments of Iran, where it has been regarded as representative of Oxfordian.$^{54}$ *V. ectypa* was recorded from the Oxfordian sediments of USA.$^{55}$ Although *A. cragini* was first described from the Lower Cretaceous of USA$^{56}$, it has been reported from Oxfordian strata by different workers in other parts of the world.$^{16,63}$ As such, the presence of *A. cragini* in lithounit JM-6 also favours assigning this unit to Oxfordian.

In view of the above discussion, it may be concluded that major part of the Chari sequence exposed at Jamara Dome accumulated during Callovian times, i.e. sedimentation commenced with lithounit JM-1 and continued up to lithounit JM-5. Thereafter, the strata belonging to lithounit JM-6 were deposited during Oxfordian times. Therefore, the Callovian–Oxfordian boundary in the studied sequence lies between lithounits JM-5 and JM-6 (Figure 5).

The present delineation of Callovian–Oxfordian boundary is tentative and needs support and/or modification with further evidence from ammonites which are abundant in these sediments, but require detailed study and revision.


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CURRENT SCIENCE, VOL. 95, NO. 3, 10 AUGUST 2008


ACKNOWLEDGEMENTS. We are grateful to the Chairman, Department of Geology, Aligarh Muslim University, Aligarh and authorities of Dhafram Samaj College, Aligarh, for providing necessary facilities. Thanks are also due to Prof. S. N. Bhalla for suggestions and constructive criticism which greatly improved the paper. K.N.G. is grateful to the University Grants Commission, New Delhi for financial support.

Received 18 December 2006; revised accepted 24 June 2008