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–Oxfrodian 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 geological investigations of the Jurassic rocks of Kutch commenced in 1837. Since then, voluminous literature has accumulated on different geological aspects of this region. As a result of these studies, Jurassic rocks of Kutch became famous all over the globe, especially for their varied and excellently preserved megafossils, including ammonites. 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 foraminifera. Most of the foraminiferal studies are devoted to systematics and taxonomy[1–8] with little emphasis on biostratigraphic, palaeoecological and palaeogeographical interpretations. In view of Kutch being placed in Category II basins with respect to its hydrocarbon prospects, comprehensive micropalaeontological studies are desirable in order to compose a vivid picture of the biostratigraphy, palaeoenvironment, palaeogeography, and tectonic history of this pericratonic basin.

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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 Foramtion is the thickest and best developed in this dome, exposing a total thick-

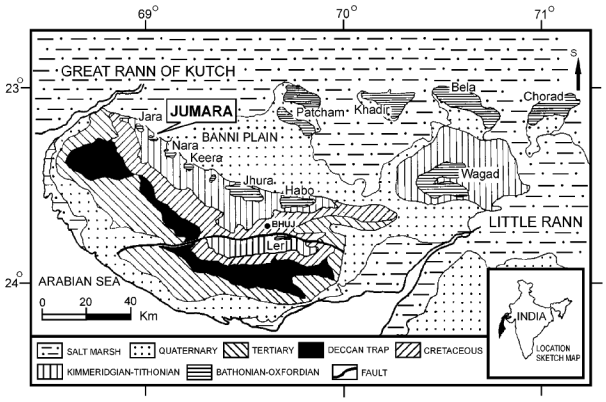

Figure 1. Geological map of Kutch showing Jumara Dome (after Fürsich *et al.*).

ness of about 245 m. In fact, the Jumara Dome is the type area of Jumara Formation, an alternate name for the Chari Formation, coined by Biswas[9] in a later proposed lithostratigraphic classification of the Jurassic rocks of Kutch.

In the Jumara Dome, good exposures of the Chari Formation are developed in two nala cuttings, locally known as Teen-phuar and Barh nalas, situated on the northern and northwestern flanks respectively, of the Jumara Dome. These sections were selected for the purpose of the present study. The Chari Formation of the Jumara 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 Jumara 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 Jumara 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 diforamens* Ireland, *Reophax tener* Siebold and Siebold, *Ammobaculites fermosus* Zieglar, *Triplasia emslandensis* Bartenstein and Brand, *Laevidentalina* aff. *L. sarthacensis* (Schwager), *Nodosaria cylindracea* Costa, *Frondicularia lignaria* Terquem, *F. nodosaria* Terquem, *Marginulinopsis instabilis* (Terquem), *Astacolus beierana* (Gümbel), *A. filosa* (Terquem), *Vaginulinopsis* 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%), Lituolidae (11.76%), Trocholinidae (5.88%), Lagenidae (3.92%) and 1.96% each of families Saccamminidae, Ammodiscidae, Hormosinidae, Haplophragmoididae, Sprillinidae, Polymorphinidae and Epistominidae.

The Jumara 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.

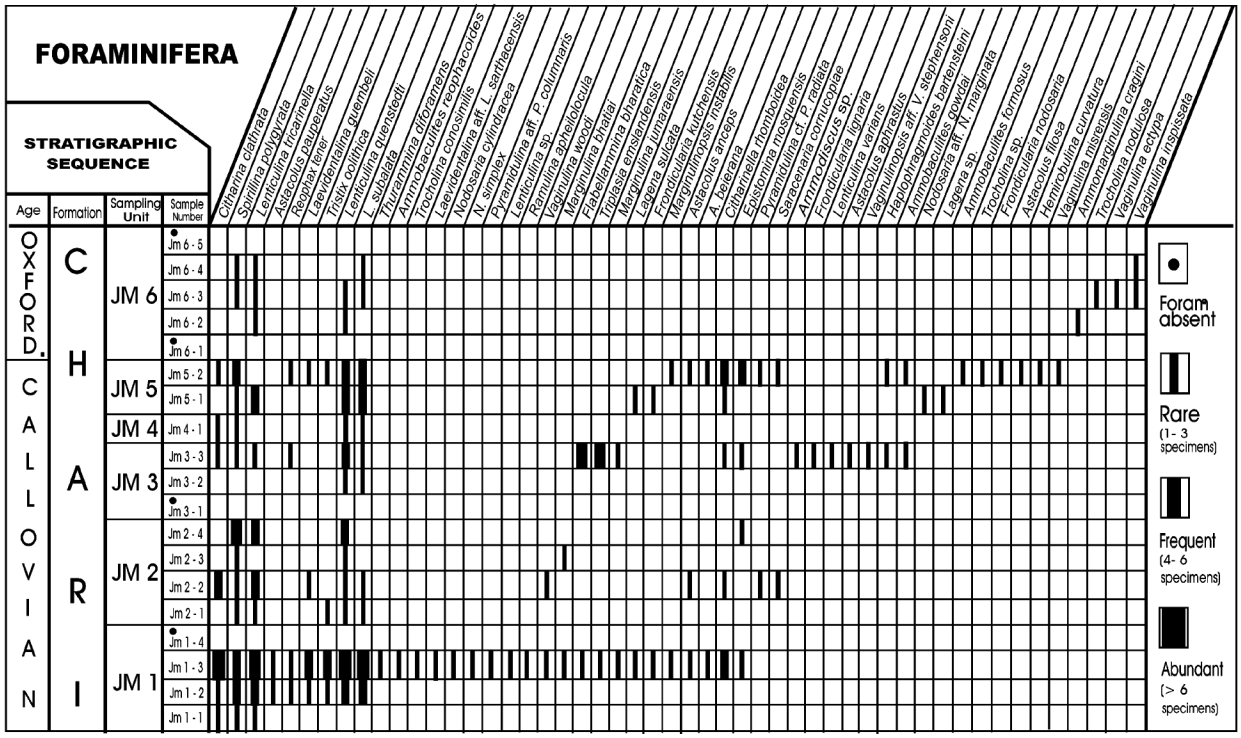

Figure 2. Frequency distribution of foraminifera in the Chari Formation, Jumara Dome, Kutch.

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[10]. 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[7,11–16]. Gradstein[17], and later Pandey and Dave[18], however, recommended the use of species of *Garantella*, *Reinholdella* and reticulate *Epistomina* in Jurassic biostratigraphy. Williamson and Stam[19] 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 vaginulinids 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[20] and the same was supported by a large number of later workers[1,3,4,7,9,13,16,18,21–31]. Spath[32] assigned a Bathonian age to the *Macrocephalus* beds, the lowermost zone of the Chari Formation. However, Aggrawal[33–35] and Arkell[36] did not favour the assigning of Bathonian age to the *Macrocephalus* beds. Some researchers[37–42] favoured a Bathonian to Oxfordian age for the Chari Formation. However, Khosla and Jakhar[43] 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[9]. Therefore, it is probably the most suitable area for investigating the lower age limit of the Chari Formation[38].

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[13]. A few species having long ranges within the Jurassic include *Spirillina polygyrata* and *Lenticulina varians*, which extend from Lias to Malm[13], whereas *Astacolus pauperatus* and *Citharina clathrata* are found to be confined to Lower and Middle Jurassic sediments of various parts of the world[13,16,44–46].

A small percentage of Jumara species have their vertical ranges within the Middle and Upper Jurassic. It includes *Vaginulina misrensis* originally reported from Kim-

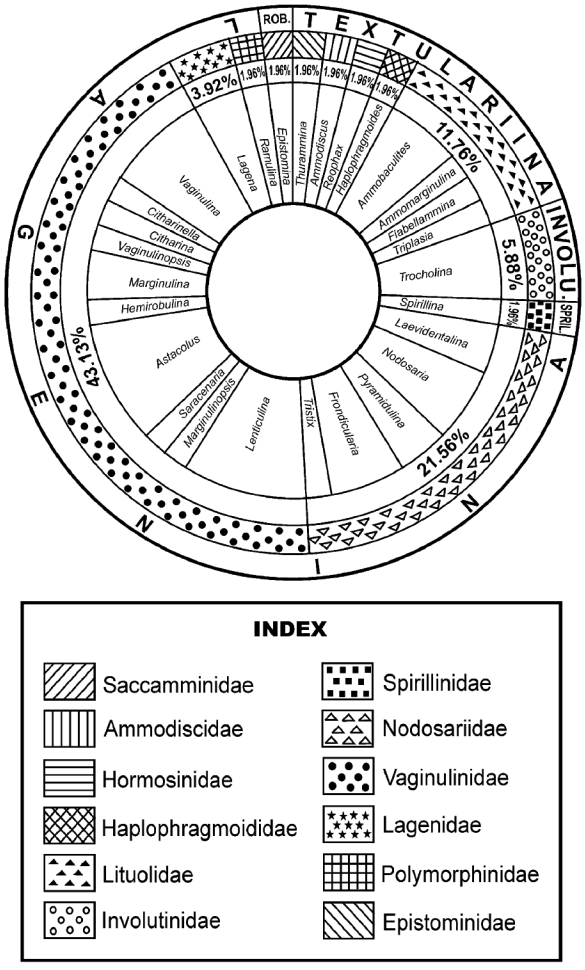

Figure 3. Composition of foraminiferal assemblage, Chari Formation, Jumara Dome, Kutch.

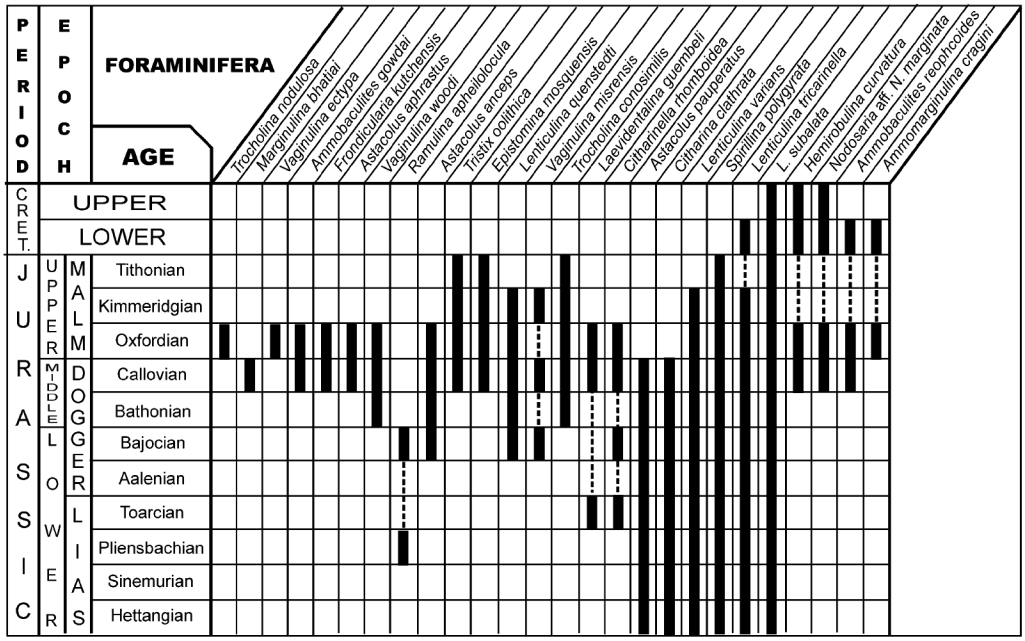

Figure 4. Known ranges of certain foraminifera from the Chari Formation, Jumara Dome, Kutch.

meridgian of Egypt[47], but later found in Bajocian of Iran[48], and Callovian of Rajasthan[15]; *Lenticulina quenstedti*, a well-known Jurassic species exhibits a continuous range from Bajocian to Kimmeridgian; *Tristix oolithica*, though ranging from Callovian to Tithonian, has mostly been recorded from Oxfordian of North America and England[49,50] and *Astacolus anceps* has been reported from Bajocian of Iran[48], Bathonian of England[45], Callovian of Scotland[50] and also from the Callovian–Oxfordian strata of different parts of the Kutch region[1,13,16,18]. Kalantari[48] recorded the frequent occurrence of *Ramulina apheilolocula* in the Bajocian sediments of northeast Iran, while it was first described from Pliensbachian of Alaska[51].

Epistomina mosquensis present in the Jumara 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, Malagasy 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 *Citharinella rhomboidea* and *Astacolus aphrastus*, which have been originally described from Oxfordian of USA[52]. However, these species have also been recorded from Callovian–Oxfordian of Habo and Jhurio domes of Kutch[13,16], as well as from Callovian of Rajasthan[15]. *Ammobaculites gowdai*, *Trocholina conosimilis*, *Laevidentalina gümbeli*, *Frondicularia kutchensis* and *Vaginulina woodi* are all known to occur in the Callovian–Oxfordian of Kutch[7,13,16,31]. Kalia and Chowdhury[15] reported the occurrence of *Trocholina* cf. *T. conosimilis* and *Laevidentalina gümbeli* from the Callovian of Rajasthan, while the latter has also been reported from the Callovian of Scotland[50] as well as Oxfordian of England[12] and Germany[53]. However, *Citharinella rhomboidea* and *Laevidentalina gümbeli* have also been reported from Middle Toarcian to Lower Bajocian and Middle Toarcian sediments respectively, of Canada[54], but these two species are found to occur commonly during Callovian–Oxfordian interval in other parts of the globe. *V. woodi* and *T. conosimilis* have also been reported from Bathonian and Bathonian to Tithonian rocks of Kutch respectively[18], but they mostly occur in Callovian–Oxfordian sediments.

Three fairly short-ranging species encountered in the Jumara assemblage include *Trocholina nodulosa* reported from Oxfordian of South Germany[55] and northeast Iran[48], *Vaginulina ectypa* described from Oxfordian of USA[52], and *Marginulina bhatiai* from Callovian of Jhurio Dome, Kutch[6].

The present assemblage also includes some foraminiferal 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. *Hemirobulina curvatura* has earlier been recorded from the Cretaceous sediments of different regions of the world[48,56–59], but this species also occurs in the Callovian–Oxfordian of Jhurio Dome, Kutch[16]. *Nodosaria* aff. *N. marginata*, originally described from the Cretaceous of Germany[60], has been recorded from the Callovian and Oxfordian of Habo Dome, Kutch[13]. *Ammobaculites reophacoides*, first

described from Lower Cretaceous of Germany[61], also occurs in the Callovian to Oxfordian sediments of Kutch[13], and *Ammomarginulina cragini*, which was first reported from the Lower Cretaceous of USA[62], has also been found in the Oxfordian of Canada[63] and Kutch[16]. *Triplasia emslandensis* 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[64] and Asia[48].

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[16], and Mandwal and Singh[40] attempted to mark the Callovian–Oxfordian boundary in the Jhurio Dome, Kutch, on the basis of foraminaferal 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 Oxfrodian, Pandey and Dave[18] regarded it as a zonal marker of the *Proteonina difflugiformis – 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[13]. 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, Jhurio Dome, Kutch[16] and this species is restricted to lithounits JM-1 and JM-2 of the present sequence.

A number of foraminiferologists have noted that *E. mosquensis*, though ranging from Callovian to Tithonian, frequently occurs in Callovian strata. Bartenstein *et al.*[44] (vide Kalantari[48]) assigned a Callovian age to *E. mosquensis* in Germany. According to Kalantari[48], the first occurrence of this species marks the base of Callovian strata and it is a representative of Callovian in Iran. Pandey and Dave[18] 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

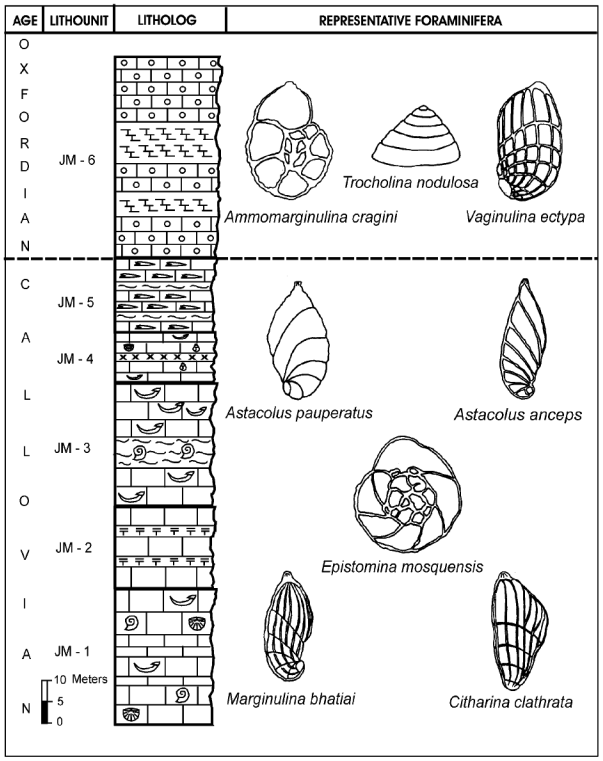

Figure 5. Callovian–Oxfordian boundary in the Chari Formation, Jumara Dome, Kutch.

may be inferred that lithounits JM-1 to JM-5 belong to Callovian.

Lithounit JM-6 of the Jumara 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[55]. It also occurs in Oxfordian sediments of Iran, where it has been regarded as representative of Oxfordian[48]. *V. ectypa* was recorded from the Oxfordian sediments of USA[52]. Although *A. cragini* was first described from the Lower Cretaceous of USA[62], 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 Jumara 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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