

# Ammonoid age control in the Mesozoic succession of Wagad outside the Mainland Kachchh\*

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Recent ammonoid investigations in the thick Mesozoic succession at Wagad, Kachchh basin suggest that the shale dominant Washtawa Formation is a lateral equivalent (in part) of the lithologically similar Chari Formation of the Mainland Kachchh, yet the ammonoid rich Jharsa Member (introduced here at the top of Washtawa Formation) is found to be of late Middle Oxfordian age, i.e., distinctly younger to the early Middle Oxfordian limit of the Dhosa Oolite Member of the Chari Formation in the Mainland Kachchh. The conformably overlying Wagad Formation is ammonoid age constrained within the Upper Oxfordian - early Lower Kimmeridgian interval. These ammonoid age constraints necessitate the rejection of the earlier held correlation and homotaxiality of the Gamdau Member (of Wagad Formation) with the Dhrangadhara Formation and Bhuj Formation, respectively located east and west of Wagad, as also the correlation of the *Astarte*-bearing Upper Oxfordian sediments of Bharodia with similar looking *Astarte*-bearing Berriasian - Valanginian sands of the Mainland Kachchh.

The submarine non-depositional hiatus between the Chari Formation and the Katrol Formation is considered to be filled -in by the Wagad Formation in the most proximal exposed part of the basin east of the median high in the Mainland Kachchh. The sea retreated from Wagad to the Mainland Kachchh in the Lower Kimmeridgian itself. The Mesozoic succession of Wagad is largely considered shallow marine of exclusive Jurassic age, with maximum bathymetry and transgression in the Kachchh basin during late Middle Oxfordian which is expressed as non-depositional submarine hiatus in major part of the Mainland Kachchh. The Wagad Formation exposed in proximal part of the Kachchh basin in Wagad is here included in an integrated lithostratigraphic framework between the Chari and Katrol units.

**Key-words**—Kachchh basin, Wagad Formation, Jurassic, Oxfordian, Kimmeridgian, Ammonoids.

## INTRODUCTION

THE ammonoid rich Jurassic - Cretaceous sedimentary succession of the Kachchh basin has been known for about 125 years including Wagad in the extreme east of the east-west striking Kachchh basin (Wynne 1872, Waagen 1871, 1873-75, Spath 1927-33, Rajnath 1932, 1942) (Fig.1). Rich ammonoid collections have been made mainly from the Mainland Kachchh, which apart from the mention of broad localities invariably lacked precise stratigraphic information. These Jurassic ammonoid collections also included substantive material from Wagad mainly from Kantkote apart from a small collection from two levels about 10 ft apart in the Iddurgarh scarp at Bharodia. These collections were studied by Waagen (1873-1875) and Spath (1927-1933) who found both Kantkolte and Iddurgarh material to be of

the same broad interval of the Oxfordian *Transversarium* and *Bimammatum* Zones. On the basis of such dating the Kantkote Sandstones, were stratigraphically placed either at the basalmost subdivision of the then Katrol 'Group' or independently in between the Chari and Katrol 'Groups' (Pascoe 1959). According to Pascoe the Wagad succession comprised a lower grey or yellowish shale division and an upper white, grey and pinkish, fine to coarse sandstones. As per tentative ammonoid determinations of Waagen and Spath, the species were found to be distinct from those of the Katrol 'Group' (now Katrol Formation), in turn suggesting an older age than that of the Katrol Formation in spite of the lithological similarity of the Wagad succession to the Katrol 'Group' of the Mainland Kachchh. The first detailed lithostratigraphic framework of Wagad sedimentary succession was made by Biswas (1977) who classified

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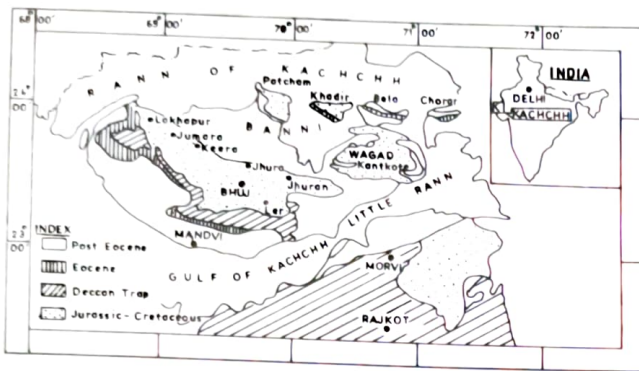


Fig.1. Schematic geological map of Kachchh.

it into two lithostratigraphic units : a lower shale dominated Washtawa Formation and an upper sand dominated Wagad Formation, the latter being divided in two members : a lower marine Kantkote Member geographically localised to Kantkote and neighbourhood, and an upper widespread non-marine Gamdau Member. According to Biswas (1977) the uppermost 100 feet shale bed of the Washtawa Formation near Kantkote included several red, ferruginous, marlstone bands which he termed as the Kantkote ammonoid bands. He suspected that the earlier ammonoid collections studied by Waagen and Spath belonged to these beds instead of the younger sandstones of the Kantkote Member in the Kantkote scarp. Further according to Biswas these ammonoid rich levels disappeared farther eastward in the Washtawa locality except for the single band at the top. Unfortunately neither Biswas cared to collect any ammonoid from the several ammonoid rich bands of the uppermost Washtawa Formation at Kantkote nor attached due stratigraphic significance to these ammonoid rich levels as given earlier by Waagen and Spath he did not make any effort to confirm or disprove his suspicion and instead correlated these ammonoid levels to the Gangta Member ammonoids north of Wagad towards the Khadir locality of 'Island belt' and assigned them an Argovian (= Lower Oxfordian) age (Fig.2). He also noted in the Kantkote Member a 24 feet interval of fossiliferous calcareous sandstone bed separating two sandstone intervals. Further, he found the upper sandstones to include a '15 feet thick' fossiliferous calcareous sandstone band in the Iddurgarh scarp (Bharodia) and referred the same as Bharodia *Astarte* band at the top. He also noted the presence of ammonoids in the Bharodia *Astarte* bands but did not assign age to these ammonoids. He also noted the presence of ammonoids in the basal shales of the Kantkote Member but inspite of mentioning in the same publication the Argovian age of the Kantkote and Iddurgarh ammonoids, he correlated the Bharodia *Astarte* bands of Wagad with the *Trigonia* bands of the Umia Formation of the West Mainland Kachchh on the basis of similar *Trigonia* (*T. smeei*) and *Astarte* (*A. major*) in

them (Fig.2). Biswas dated them as Valanginian in view of similar bivalve taxa occurring in Umia Formation and also in South Africa (Spath, 1930). Further he assigned the Wagad Formation an Upper Oxfordian to Pre-Aptian Lower Cretaceous age and held it equivalent to Jhurian Formation and Lower Member of Bhuj Formation of the Mainland Kachchh. Biswas in his intrabasinal correlation in the same work correlated the Bharodia *Astarte* band with the top of the Middle Member of Jhurian Formation of the East Mainland Kachchh (Fig.2). Biswas (1977) found the Gamdau Member of the Wagad Formation similar to Bhuj Formation of the Mainland Kachchh in gross lithofacies and geomorphic expressions and suggested the continuation of the Gamdau Member with the Dhrangadhara Sandstones of Kathiawar underneath the Rann farther east. He established by actual mapping the time equivalence of the Gamdau Member of Wagad Formation with the Kantkote Member in greater part of the area east of Ropar - Chitrod line but with the Gamdau Member at the edge of the highland and Islands of the little Rann. Biswas (1977) also considered the Gamdau sandstones as of deltaic environment characterized by the intertonguing of the marine and non-marine facies in the delta front zone at the cratonic border of a marginal basin.

## OBSERVATIONS

The Kachchh Jurassic - Cretaceous ammonoid succession has been studied with a view to improve the resolution of time in the Kachchh Jurassic succession in reference of the internationally correlatable scheme of

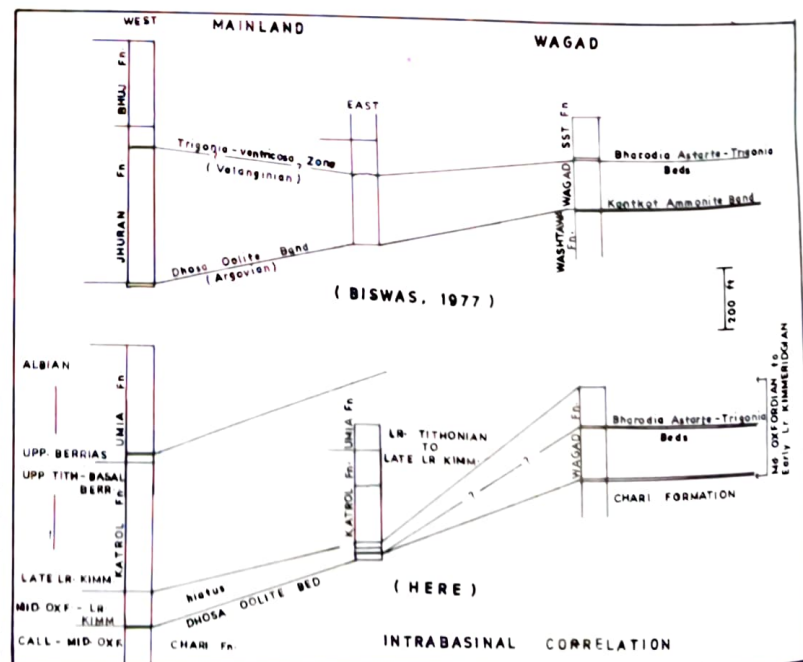


Fig.2. Intrabasinal correlation between the Mainland Kachchh and Wagad, Kachchh Basin.

ammonoid zones. Such high resolution ammonoid successions have been developed for the Callovian, Kimmeridgian and Tithonian stages in the Mainland Kachchh (Krishna *et al.* 1995a, Krishna & Ojha 1996). However, the Oxfordian succession was found to be extremely incomplete and also inadequately developed in the Mainland Kachchh in view of extreme low sedimentation rate, strong condensation and presence of submarine hiatus (Krishna 1990, 1991, Krishna *et al.* 1994a, b, 1995b). We anticipated better development of the Oxfordian interval farther east outside the Mainland Kachchh in Wagad region. In our first and the only field visit to Kantkote locality of Wagad, we collected ammonoids with stratigraphic precision from over 20 levels from the uppermost 10m Washtawa Formation and also from Kantkote Member inclusive of Bharodia *Astarte* band of Biswas (1977) (Fig.3). It was possible to establish that the rich Kantkote ammonoid fauna described earlier by Waagen and Spath came from the uppermost part of Washtawa Formation and not from Kantkote Member in the Kantkote scarp as misunderstood earlier. We found the Washtawa Formation fauna to be precisely of Middle Oxfordian *Transversarium* Zone, *Schilli* Subzone (Krishna *et al.* 1994a, b, 1995b) (Fig.3) while the Iddurgarh - Bharodia ammonoid levels have been found to straddle the latest Upper Oxfordian *Bimammatum* Zone/earliest Lower Kimmeridgian *Platynota*

Zone interval (Fig.3). In spite of the earlier imprecisely collected ammonoids, our age bracket Middle Oxfordian *Schilli* Subzone to Oxfordian/Kimmeridgian boundary except for higher precision agrees with the earlier observation of Waagen and Spath. However, unlike the contention of Spath (1927-33), the Kantkote ammonoid bands belonging to the Washtawa Formation are distinctly older than the ammonoid levels of the Iddurgarh scarp.

While we intend to continue our investigation of the ammonoid succession in Wagad for developing a high resolution ammonoid scheme as already achieved in Callovian, Kimmeridgian and Tithonian stages in the Mainland, our preliminary results (Krishna *et al.* 1996a, b, 1995a; Krishna & Ojha 1996) call for significant revision of the integrated geological comprehension of the Jurassic succession in Wagad. The main aspects discussed here are: (1) Precise age duration, (2) Correlation and (3) integration in the Kachchh lithostatigraphy.

1. *Precise age Duration*-The lower age limit of the Wagad succession (Jurassic) still remains imprecise in view of the absence of chronologically significant am-

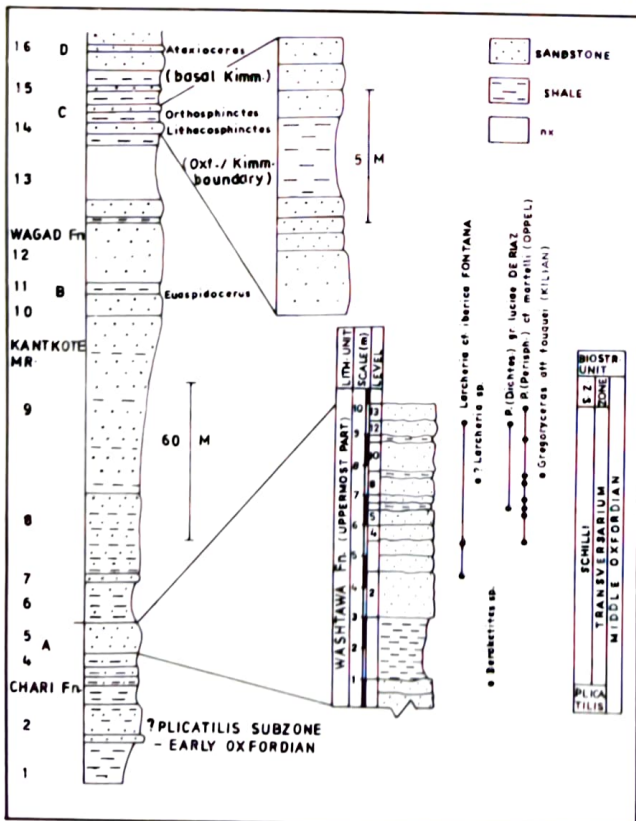


Fig.3. Composite lithocolumn with ammonoid levels of the Oxfordian - early Lower Kimmeridgian sedimentary succession at Wagad.

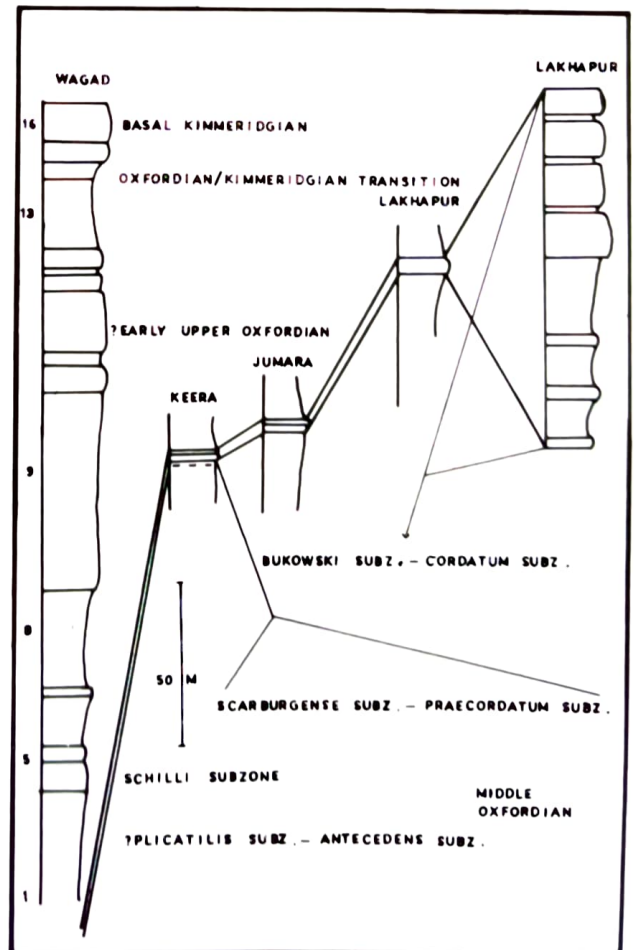


Fig.4. Correlation among the Oxfordian successions of Keera, Jumara and Lakhapur localities of Mainland Kachchh with Wagad.

monoids in the major part of the Washtawa Formation. In the regional set up it may not extend below Callovian, since similar shale dominant Chari Formation all over the Mainland Kachchh has its base dated in the early Lower Callovian. Our ammonoid studies for the first time have precisely determined the top of the Washtawa Formation as of Middle Oxfordian *Transversarium* Zone, *Schilli* subzone (Fig.3). This is primarily based on the first definite record of the Middle Oxfordian *Transversarium* Zone Mediterranean ammonoid index *Gregoryceras* of the *Transversarium - fouquei* group, Sub-mediterranean *Larcheria* gr. *Schilli* (Krishna *et al.* 1995b). The base of the succeeding Wagad Formation is also dated in the Middle Oxfordian *Transversarium* Zone on the extremely rare presence of *Grayiceras*. The top of the Kantkote Member in the Iddurgarh scarp is placed in the uppermost Oxfordian *Bimammatum* Zone with possible extension in the earliest Lower Kimmeridgian *Platynota* Zone based on the ammonoid evidence of *Ataxioceras*, etc. (Fig.3). We consider, as discussed later, that the youngest ammonoid-devoid Mesozoic lithostratigraphic unit is mostly a facies equivalent in time of the Kantkote Member and therefore also should not extend in age beyond the earliest basal Kimmeridgian *Platynota* Zone. Thus, as a whole, the Wagad sedimentary succession is limited to Callovian - Oxfordian interval with possible extension into the earliest Lower Kimmeridgian *Platynota* Zone. This is in contrast to the Callovian (late Middle Jurassic) - pre-Aptian (Lower Cretaceous) age assigned earlier by Biswas (1977). In terms of the absolute duration, the Wagad succession corresponds to a duration only of about 12 to 14 my instead of the huge 50 my duration given by Biswas.

2. *Correlation*- It may be noted that Biswas based his correlation of the Wagad Mesozoic succession with the Mainland succession (Fig.2) on the basis of two fossiliferous marker beds of the Wagad succession, (i) the correlation of the ammonoid rich youngest Washtawa Formation levels with the Dhosa Oolite of the Mainland Kachchh and its assignment to Argovian. Our ammonoid studies in the Mainland Kachchh and Wagad have found the top of the Washtawa Formation distinctly younger to that of the Dhosa Oolite Member of the Mainland Kachchh (Fig.4) by at least one ammonoid zone 'i.e.' with a difference of at least 1 my. This interval in most of the Mainland Kachchh is represented in the submarine nondepositional hiatus (Fig.5); (ii) The Bharodia *Trigonia - Astarte* band in the upper part of the Kantkote Member has been correlated by Biswas to the top of the shaly Middle Member of the Jhuran Formation in the East Mainland Kachchh (the Jhuran - Rudramata sections) and to the *Trigonia - Astarte*

band/bed in the lower part of the sandy Upper Member of the Jhuran Formation in the West Mainland Kachchh (Fig.2). The basis of this correlation, according to Biswas was the similarity of the bivalve species present in the respective beds of Wagad and Mainland Kachchh. All these three correlated intervals were dated by Biswas as Valanginian in view of the possible Valanginian age of similar bivalve bearing beds in S. Africa (Spath 1930). According to the present investigation, the Bharodia *Trigonia - Astarte* band belongs to the uppermost Oxfordian *Bimammatum* Zone *Orthosphinctes*, *Lithacosphinctes*, *Ataxioceras*, collected by us in association of the said bivalves (Fig.2). In contrast the top of the shaly Middle Member in the Jhuran section on our ammonoid evidence (*Hybonotoceras*, etc.) is precisely placed in the lower part of the uppermost Kimmeridgian *Katrolensis* Zone equivalent to the lower part of the North Tethyan uppermost Kimmeridgian *Beckeri* Zone. As such the Bharodia *Trigonia - Astarte* band of Wagad is nearly one full stage older than the East Mainland Kachchh level to which it has been correlated by Biswas. The difference in the two correlated levels in absolute terms is of the order of 5 to 6 my. The *Trigonia* beds in the lower part of the Upper Member of the Jhuran Formation in the West Mainland Kachchh on independent ammonoid evidence from below and above Lower Berriasian *Argentinoceras* (Krishna 1991) in the youngest of the two ammonoid rich green oolite beds below the *Trigonia* beds, and Lower Valanginian *Kilianella* in the conglomeratic gritty sandstone above the *Trigonia* beds in the Sahera and Mundhan section of the West Mainland Kachchh is dated as mostly of Berriasian age instead of the earlier assignment to Valanginian. Obviously the *Trigonia* beds of West Mainland Kachchh are at least 12 my younger than the Bharodia *Trigonia - Astarte* band of Wagad to which it was correlated earlier by Biswas. The Wagad Formation eastward has been broadly correlated to Dhrangadhara Formation of Kathiawar on the basis of similar lithologic facies and geomorphic similarities. It was even suggested by Biswas that the

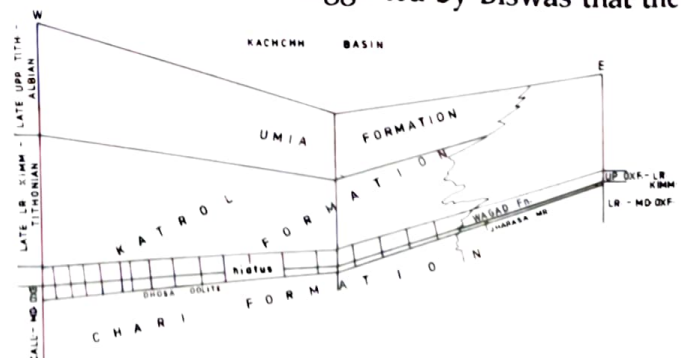


Fig.5. Mesozoic stratigraphic set-up in the Mainland Kachchh showing significant submarine non-depositional hiatus between the Chari and Katrol formations.

Wagad Formation most possibly exhibits lateral continuity underneath the Rann to the Dhrangadhara Formation. The Dhrangadhara Formation in spite of lack of firm evidence is by one and all assigned to Lower Cretaceous. It is clear from the discussion above on the dating of the Bharodia *Astarte* band of Wagad Formation that its correlation with the Dhrangadhara Formation is incorrect. Thus all the earlier correlations of Biswas, (i) of Wagad Formation with Dhrangadhara Formation, (ii) of Bharodia *Trigonia* beds with the top of shaly Middle Member of Jhuran Formation in the East Mainland Kachchh and with *Trigonia* beds in the early part of the Upper Member of Jhuran Formation are untenable (Fig.2). The Bharodia *Astarte* band of Wagad Formation is distinctly older to the three fossiliferous intervals with which it was correlated. It is older to the Dhrangadhara Formation by about 50 my, to top of the Middle Member of Jhuran Formation of the East Mainland Kachchh by about 6 my, and to the *Trigonia* beds in the early part of the Upper Member of Jhuran Formation in the West Mainland Kachchh by about 12 my. In context of the Mainland Kachchh succession, the top of the Washtawa Member is placed above the Dhosa Oolite Member of the Mainland Kachchh in the submarine nondepositional hiatus. The Bharodia *Trigonia* - *Astarte* interval is also placed in the submarine non-depositional hiatus above the top of the Washtawa Formation and below the basal part of Katrol Formation (late Lower Kimmeridgian *Alterneplicatus* Zone). Similarly the Wagad Formation is stratigraphically placed in the submarine non-depositional hiatus in between the Chari and Katrol Formations (Fig.5).

3. *Integrated Lithostratigraphy*- Our record of the lithological succession of Wagad and its precise age assignment demonstrates clearly that the shale dominated Washtawa Formation is only a lateral extension of the shale dominated Chari Formation exposed only in the Mainland Kachchh and 'Island belt' while the top of the Chari Formation is extended upwards up to the top of the Washtawa Formation instead of upto the top of Dhosa Oolite of the Mainland Kachchh. We have found that the topmost 10m ironstone carbonates both lithologically and chronologically are different from the Dhosa Oolite Member of Chari Formation. Like the Dhosa Oolite of the Mainland Kachchh, these ironstone carbonates represent a stratigraphic marker in most of Wagad with gradual pinching out farther east. To differentiate lithostratigraphically it with the older Dhosa Oolite, we here introduce Jharasa Member for these ironstone carbonates (Fig.5) of Wagad as the youngest lithostratigraphic unit of the Chari Formation above the Dhosa Oolite Member and below the Kantkote Member of Wagad Formation. At the same

time we abandon the Washtawa Formation of Biswas (1977) and instead consider it as a lateral equivalent of the Chari Formation with similar lithology and broad age bracket. Further we accept the Wagad Formation of Biswas and include it in the Kachchh Mesozoic lithostratigraphic framework, because the interval of Wagad Formation falls in the submarine nondepositional hiatus in the Mainland Kachchh. Lithologically, also Wagad Formation is distinct from the shale dominated Chari Formation below as also from the shale dominated Katrol Formation above. Thus Wagad Formation is easily intergrated in the Kachchh Mesozoic lithostratigraphic framework underlain by the Chari Formation and overlain by the Katrol Formation in a revised five unit framework (Patcham, Chari, Wagad, Katrol and Umia formations) (Fig.5). The Wagad Formation as indicated earlier ranges in age from late Middle to Upper Oxfordian with possible extension in early Lower Kimmeridgian (Fig.2). Laterally, the Wagad Formation of Kachchh has found expression only in the Wagad region which is the most proximal exposed part of the Kachchh basin (Fig.5). Distally, in the west of the East Mainland Kachchh the equivalent interval marks the submarine nondepositional hiatus (Fig.5). This is quite consistent with the predictable migration of lithofacies as also in the significant variation of the sedimentation rate from relatively deeper part of the Kachchh basin in the Mainland Kachchh to the relatively shallower part of the Kachchh basin outside the Mainland Kachchh in the Wagad region.

## CONCLUSION

The study of the ammonoids in the sedimentary succession of Wagad has resulted in a major revision of its stratigraphic set up. Instead of a large Callovian (late Middle Jurassic) - pre-Aptian (Lower Cretaceous) duration is here assigned to Callovian - Oxfordian duration with possible extension in the earliest Lower Kimmeridgian. The *Trigonia* - *Astarte* bivalve bands of West Mainland Kachchh, East Mainland Kachchh and Wagad instead of being time correlatives are considered expressions of similar recurrent biofacies of different ages in different sections, Berriasian in the West Mainland, latest Kimmeridgian in the East Mainland and late Upper Oxfordian in Wagad.

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