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# AN OVERVIEW OF THE MESOZOIC STRATIGRAPHY OF KACHCHH AND JAISALMER BASINS

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ABSTRACT

The Mesozoic sedimentary basins on the western margin of India have remained largely unexplored for hydrocarbons. Still, among these, the basins of Kutch and Jaisalmer are better known geologically. These owe their formation to rifting along the major Precambrian lineaments in the Western India-East Africa divergent plate region prior to the fragmentation of the Gondwana Superplate. The successions in both these basins are thick, well developed and organically rich exhibiting a fair degree of stratigraphic similarity. The sediments, except for the Middle Jurassic carbonates, are dominantly clastic. Lithostratigraphically, the older schemes (of Stoliczka in Kutch and of Oldham in Jaisalmer) are found well founded and valid in terms of the modern concept of stratigraphic terminology vis-a-vis propositions made later over the years. Stratigraphically the ammonoid studies in recent years have facilitated the extension of both the lower and upper limits of the succession in Kutch and only upper limit in Jaisalmer, and these sediments now range in age from atleast Bajocian (Lower Jurassic/Upper Triassic is present in Jaisalmer and also suspected in Kutch) to Albian. Standard stages, intrastage divisions, fossil assembleges, intra and inter-basinal correlation, and also several time boundaries viz. Bathonian/Callovian, Lower/Middle Callovian, Callovian/Oxfordian, Basal Tithonian, Jurassic/Cretaceous, Neocomian/Aptian, Aptian/Albian are now better understood with strengthened control. Environmentally, facies reinterpretation has lately advocated marine origin also for the traditionally held plant fossil bearing non-marine part of the succession with similar suggestion for Jaisalmer. In general trasgressive facies dominate until the close of Oxfordian and thereafter a regressive regime takes over until withdrawal of the sea inthe Albian.

Hydrocarbon possibilities as broadly suggested by the stratigraphic and depositional framework have also been discussed briefly.

## INTRODUCTION

Among the sedimentary basins of India, those belonging to the Mesozoic time span constitute a significant number, and these have begun receiving increasing attention inrecent years, particularly in context of oil

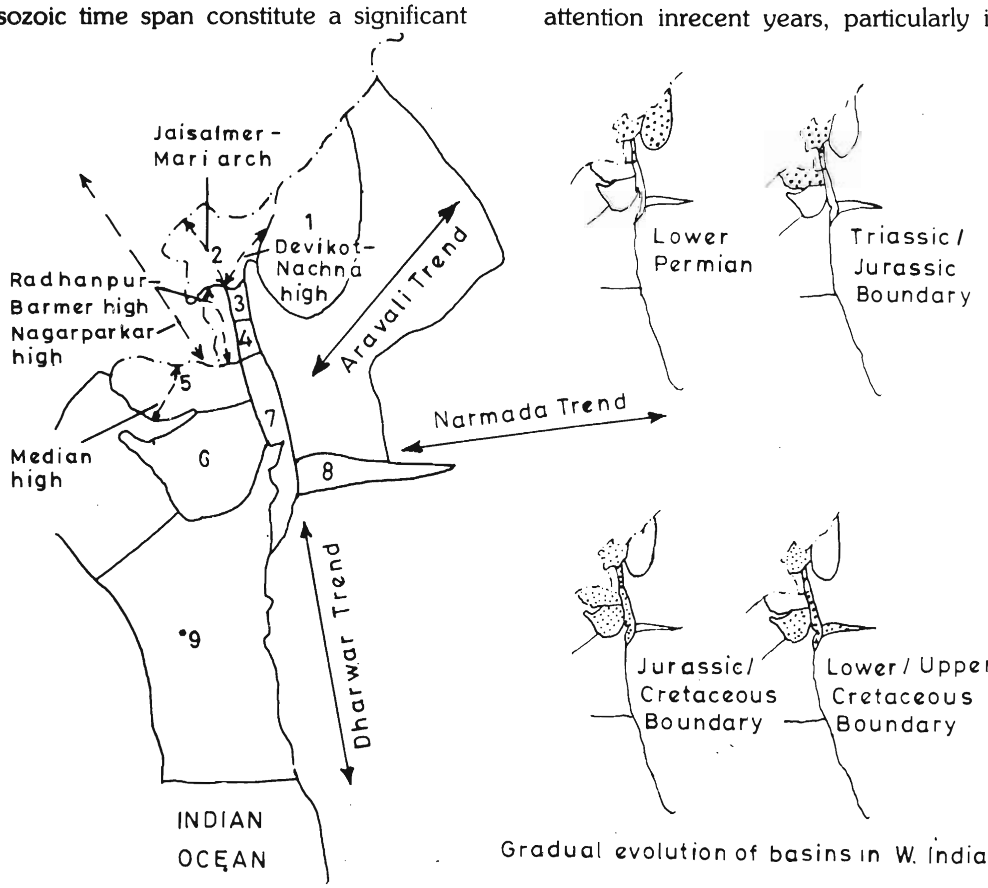


Fig. 1 Evolution of sedimentary basins in western India during Mesozoic.

Table 1. Synthesis of the Mesozoic Stratgraphy in Western India

| ERA | PERIOD | PERIOD/STAGE | AB-K-S | K-P | J | B-N |
|---|---|---|---|---|---|---|
| MESOZOIC ERA | CRETACEOUS | MAESTRICTIAN | Parh Fn. | Pab Fn. | Dep. Gap | Dep. Gap |
| | | SENONIAN | | Kawagarh Fn. | Parh Fn. (In subcrop) | |
| | | TURONIAN | | | | |
| | | CENOMANIAN | Goru Fn. | Lumshiwal Fn. | Goru Fn. (In subcrop) | |
| | | ALBIAN | | | | |
| | | APTIAN | | | Abur Fn. | |
| | | BARREMIAN | Sember Fn. | | Parihar Fn. | |
| | | HAUTERIVIAN | | | | |
| | | VALANGINIAN BERRIASIAN | | | | |
| | JURASSIC | TITHONIAN | Dep. Gap. | Chichala Fn. | Bhadasar Fn. | |
| | | KIMMERIDGIAN | | | | |
| | | OXFORDIAN | | | Jaisalmer Fn. | |
| | | CALLOVIAN | Mazardrik Fn. | Dep. Gap | | |
| | | BATHONIAN | | Samanasuk Fn. | | |
| | | BAJOCIAN | Chiltan Fn. | Shinawari Fn. | | |
| | | AELENIAN | Shirinab Fn. | | | |
| | | TOARCIAN | | | Lathi Fn. | |
| | | PLIENSBACHIAN | | Datta Fn. | | |
| | | SINEMURIAN | | | | |
| | | HETTANGIAN | | | | |
| | | TRIASSIC | Wulgai Fn. | King. Fn. Tredian Mianwali | Shumerwali Fn (In subcrop) | |
| PERMIAN | | | ? | ? | Karampur Fn. (in subcrop) | Badhaura Fn. Bap Fn. |

| B | S | K | S |
| --- | --- | --- | --- |
| Dep. Gap | Deccan Trap | Deccan Trap | Deccan Tr |
| | Dep. Gap | Dep Gap | Wadhwan Fn. |
| | Serau Fn. (In subcrop) | Umia Fn. | Dep. Gap |
| Fatehgarh Fn. | | | |
| Volcanics | | | Dharangd Fn. |
| Dep. Gap | | | |
| | Dep. Gap | Katrol Fn. | Dep. Gap |
| Jaisalmer Fn. | | Chari Fn. | |
| | | Patcham Fn. | |
| Lathi Fn. | | Unnamed unit (In subcrop) | |
| Dep. Gap | | | |
| | | Dep. Gap | |

| | C | N | B |
|---|---|---|---|
| ap | Deccan Trap | Deccan Trap | Deccan Trap (In subcrops) |
| | Unnamed unit (In subcrop) | Bagh Group | Dep. Gap |
| | ? | Dep. Gap | |
| hra | | | |
| | Dep. Gap | | |

exploration. The Mesozoic basins, excepting the essentially landlocked fluvial ones, are mostly distributed on the margin of the Indian plate (inclusive of the neighbouring Pakistan, Nepal, Bhutan etc.), and have been grouped into 3 sectors; in the west, north and east respectively (Krishna, 1983b). The western sector mainly includes Narmada, Cambay, Saurashtra, Kachchh and Sanchore basins in Gujarat; Barmer, Jaisalmer, Bikaner-Nagpur basins in Rajasthan; and Axial Belt, Lower Indus and Upper Indus Basins in Pakistan (Table 1). The principal basins of the northern sector are along the Higher Himalaya (Tibetan or Tethys Himalaya), while the basins in the eastern sector are those of Palar, Cauvery, Krishna and Godavari along the eastern coast of India.

The higher Himalaya basins mostly received continuous sedimentation since the beginning of Phanerozoic or earlier. On the other hand those of the western and eastern sectors originated in successive impulses in response to initiation of rifting activity in India-Africa and India — Antarctica + Australia divergent plate regions of the composite Gondwana superplate. In general the basin evolution process began first in the western sector (details discussed later) near the Triassic/Jurassic boundary, and proceeded from north to south (Fig. 1).

Many of the Mesozoic basins particularly in the northern sector essentially comprise marine sediments only, while some of the western and eastern sectors are traditionally held as 'mixed' i.e. partly marine and partly non-marine inter-calated sequences. This understanding is based on their prolific plant-bearing and easily recognisable marine body fossil-lacking character in a part of the sequence. Since the plant fossils that these 'mixed' successions enclose are similar to those of the landlocked inland fluvial Upper Gondwana units. these were also often referred to as Coastal Upper Gondwana. Recently in a case study based on mutlidisciplinary depositional facies interpretation of such a mixed sequence in Kachchh (Krishna, Singh, Howard & Jafar 1982, 1983 and Krishna 1982, 1983b), an essentially marine origin has been proposed for these so called 'mixed' or 'Upper Gondwana' sequences.

Among the different basins inthe western sector, the Mesozoic basins of Kachchh and Jaisalmer range from Triassic to well up into the Upper Cretaceous. These enclose 1500-3000 m thickness in Kachchh and about 800 m in Jaisalmer respectively covering 43,000 sq km and 30,000 sq km of areas (inclusive of about 15,000 sq kms and 8000 sq kms of exposed Mesozoic sedimentary areas).

## TECTONIC AND PALEOGEOGRAPHIC FRAMEWORK

The basins of Jaisalmer and Kachchh along with other basins in the western sector originated in response to reactivation of ancient fracture zones on the western margin of the Indian plate. This reactivation was part of the overall rifting history of the Gondwana super plate. The rifting in the region initiated at the start of the Permian and in general proceeded from north to south. The Indian shield had already emerged out after an extensive and widespread Vindhyan sedimentation north of the Narmada lineament and was positive area upto the close of Carboniferous period. The Bikaner-Nagaur and Jaisalmer areas of Western Rajasthan and Axial Belt, Kirthar-Sulaiman and Kohat-Potwar areas of Pakistan formed its north-western slopes which were bounded on the three sides by the basement ridges of the Aravalli-Delhi fold belt (NW-SE Aravallis inthe southeast, Delhi-Sargodha ridge in the northeast and Delhis in the south).

Near the Triassic Jurassic boundary a strong activation impulse, was experienced inthe region accompanied by igneous activity along the Axial Belt. An alround uplift was expressed in most of the Axial belt and Indus Shelf areas but sedimentation continued in the Jaisalmer basin. The Barmer basin opened along the NW-SE Dharwar trend southeast of Jaisalmer between uplifts of the Delhi-Aravalli folded basement on its either side. Around the same time also originated the E-W trending Kachchh basin parallel to the Narmada trend between Nagar-Parker uplift inthe north and Kathiyawar uplift in the south (also see Biswas, 1980). It is significant that after the origin of Jaisalmer basin in Lower Permian the evolution of other basins inthe western sector proceeded from north to south at different dates as indicated in Fig. 1.

Although extending to the Indus Shelf beyond the India-Pakistan border in the northwest and northeast, the Jaisalmer basin is practically bounded by the border with Pakistan in these directions. The Devikot-Nachna uplift, separates it in the southeast from the Barmer basin and in the east from Bikaner-Nagaur basin. Nagar-Parker basement ridge delimits the Jaisalmer basin from the Axial Belt region of Pakistan, while the northwestern end of the Delhi-Lahore ridge demarcates the Jaisalmer basin inthe northeast from the Punjab shelf. On the other hand the Kachchh basin is an EW protected bay. On the eastern side it is bounded by the Radhanpur-Barmer ridge and by Delhi-Aravalli basement ridges in the north. The Saurashtra peninsula delimits the Kachchh basin on the south (Fig. 1).

## STRATIGRAPHY

The sedimentary sequences in the Mesozoic basins of Jaisalmer and Kachchh are thick, well developed and prolificly fossiliferous exhibiting a fair degree of homotaxiality (Tab. 2). The temporal control is mostly provided by ammonoids. The lowest ammonoid date in Kachchh is Upper Bajocian (Singh, Jaitly and Pandey *et al.*, 1981) while in Jaisalmer it is Upper Bathonian (Krishna and Westermann, 1985); however in both the basins these levels are underlain by ammonoid devoid sediments. It may be noted that presence of Upper Triassic/Lower Jurassic has been suggested in the Banni well subcrops (Koshal, 1983). The youngest ammonoid date from the outcrop area of both the basins is late Lower or early Middle Albian (Krishna, 1980a, b and 1983a, b and Krishna *et al.* 1982, 1983). In Jaisalmer this Upper ammonoid date is from the top of the Mesozoic succession (Abur Formation) while in Kachchh it is from the top of the Ukra Member (of Umia formation) which in turn is overlain by 300 m thick Bhuj Member. The sediments except for the Middle Jurassic carbonates are dominantly terrigenous clastics. The sedimentation in general typifies cyclic shallow marine shelf type often under protected conditions. Cyclic repititions of lithology, presence of reefoidal build-ups, coquina beds, intensely bioturbated oxidised grits and sandstones, quick vertical and lateral variation in lithology, persistence of nearly the same suite of trace fossils throughout the succession, dominance of nearshore shallow-water benthonic communities, physical structures characterise labile (semistable to unstable) platform sedimentation under rapidly fluctuating sea. In relative terms Jaisalmer basin shows less instability than Kachchh and is much less affected structurally by Mesozonic or later tectonics. (See Tables 1-5; Figs 2-5).

KACHCHH BASIN

Stoliczka's unpublished four-fold (Patcham, Chari, Katrol and Umia Groups) lithostratigraphic scheme (first used in Waagen, 1873-75) for Kachchh is well founded, and has been in wide and extensive usage for well over a century. The scheme was originally proposed principally on lithological considerations. Later workers used these units inconsistently as 'Series', 'Formation', 'Bed', 'Stage', etc. Such improper and arbitrary use in either lithostratigraphic or chronostratigraphic sense for the same names was mainly due to lack of code of stratigraphic nomenclature as available presently. The scheme with minor modifications made over the years, but retaining its basic framework is 1. Patcham Formation (Upper Bajocian or older to Upper Bathonian or Lower Callovian), 2. Chari Formation (Upper Bathonian to Upper Oxfordian), 3. Katrol Formation (Kimmeridgian to Middle Tithonian) and 4. Umia Formation (inclusive of Bhuj as its youngest member) (Upper Tithonian to Upper Albian). Rajnath (1932, 1942) demonstrated the mappability of Stoliczka's units by bringing out 4" to a mile scale geological map of northwestern Kachchh. His introduction of Bhuj unit as a subunit within Umia Formation was essentially within the basic framework of Stoliczka's scheme. Agrawal (1956, 1957 and 1981) replaced the name Chari 'Series' by Habo 'Series' and Dhosa Oolite by 'Mebha Oolite'. Much has been said about this (Biswas, 1971 and 1977), the author would only state here that instead of these new propositions Agrawal's main objections could have been removed by proposing the Habo section and Medisar-Bakhri composite section as reference sections for fuller and better understanding of Chari Formation. Biswas (1971) based on extensive field studies in Kachchh proposed altogether new lithostratigraphic schemes separately for Mainland, Wagar and the 'Island' belt. He found Stoliczka's prevalent scheme unacceptable on account of lack of precise definition with respect to designated type sections, mappability, improper use of stratigraphic nomenclature and ambiguity in terms of modern concept of stratigraphy.

It may be stated here that the above objections could have been removed by elaborate definition of of the type sections, by suggesting appropriate usage of stratigraphic terminology for removing the ambiguity whatsoever as has been done in case of other classical sequences of India. New schemes with new set of names for the same stratigraphic units were neither called for nor were able to remove the confusions. On one hand the new schemes as well as his objections to the old scheme were contested and questioned by Mitra, Baradhan & Ghosh (1979) while Kanjilal (1978), Agrawal and Kachhara (1977), Agrawal and Kacker (1978) and many others proposed local schemes with new names for successions in individual hills. The author is of the opinion that all possible efforts should be directed for refining and perfecting the long prevalent schemes rather than abandoning them for their small removable lacuna in favour of new propositions. The present work has found favour with Stoliczka's old scheme with minor adjustments within its basic framework. Nomenclature of the Cretaceous part of the succession has already been discussed (Krishna, 1983b), and only a brief reference to the Jurassic part is attempted here. In the opinion of the author the Patcham/Chari formational boundary is better defined at the top of the Greyish Wite limestone with the limestone dominated lower part falling in Patcham Formation and the ensuing shaly sequence going to the Chari Formation in comparison to the 'Jhurio'/'Jumara' lithostratigraphic boundary of Biswas (1977). The 'Jumara Formation' essentially refers to the same physical succession of beds for which Stolizzka's Chari Formation had long been inusge. The upper boundary of Chari as well as 'Jumara' units are defined by the top of the Dhosa Oolite Member. The section at Jumara also exposes the Chari Formation in full and can serve as an excellent reference section for a fuller and better understanding of the Chari Formation, instead of a new name 'Jumara Formation' for Chari

Table 2. Stratigraphic Similarliy between Mesozoic Units of Jaisalmer and Kachchh.

<table>
<tr><th colspan="3">J A I S A L M E R</th></tr>
<tr><td colspan="2">GORU FORMATION<br>(in subcrops only)</td><td>Mainly shales with glauconites</td></tr>
<tr><td colspan="2">HABUR FORMATION<br>Lower Aptian to<br>Lower or early<br>Middle Albian</td><td>Mainly limestones</td></tr>
<tr><td colspan="2">PARIHAR FORMATION<br>Upper Tithonian<br>to Neocomian</td><td>Mainly sandstones</td></tr>
<tr><td colspan="2">BHADASAR FORMATION<br>Kimmeridgian to<br>Middle Tithonian</td><td>Mainly sandstones above and shales below</td></tr>
<tr><td rowspan="2">JAISALMER<br>FORMATION<br>Bajocian to<br>Oxfordian</td><td>KULDHAR<br>MEMBER</td><td>Mainly shales and limestones with colites</td></tr>
<tr><td>JAISALMER<br>MEMBER</td><td>Mainly limestones</td></tr>
<tr><td colspan="2">LATHI FORMATION<br>Lower Jurassic</td><td>Mainly sandstones</td></tr>
<tr><td colspan="2">SHUMERVALI<br>FORMATION<br>Triassic<br>(in subcrops only)</td><td>Mainly sandstone</td></tr>
</table>

## K A C H C H H

| | | |
|---|---|---|
| UMIA FORMATION<br>Upper Tithonian to<br>Upper Albian | BHUJ MEMBER | Mainly sandstone |
| | UKRA MEMBER | Mainly shales and sandstones<br>with oolites and glauconites |
| | GHUNERI<br>MEMBER | Mainly sandstones and<br>shale alternations |
| | UMIA MEMBER | Mainly marls with oolites<br>and glauconites |
| KATROL FORMATION<br>Kimmeridgian to<br>Middle Tithonian | | Mainly sandstones above and<br>shales below |
| CHARI FORMATION<br>Upper Bathonian<br>to Oxfordian | | Mainly shales with hard<br>oolitic limestones bands |
| PATCHAM FORMATION<br>Bajocian to Upper<br>Bathonian | | |
| Unnamed unit<br>(in subcrops only)<br>late Upper Triassic<br>to Lower Jurassic | | Mainly sandstones and lime-<br>stones with shale interbeds<br>(max. limestones in this unit) |
| | | Mainly sandstones |

Stratigraphic break

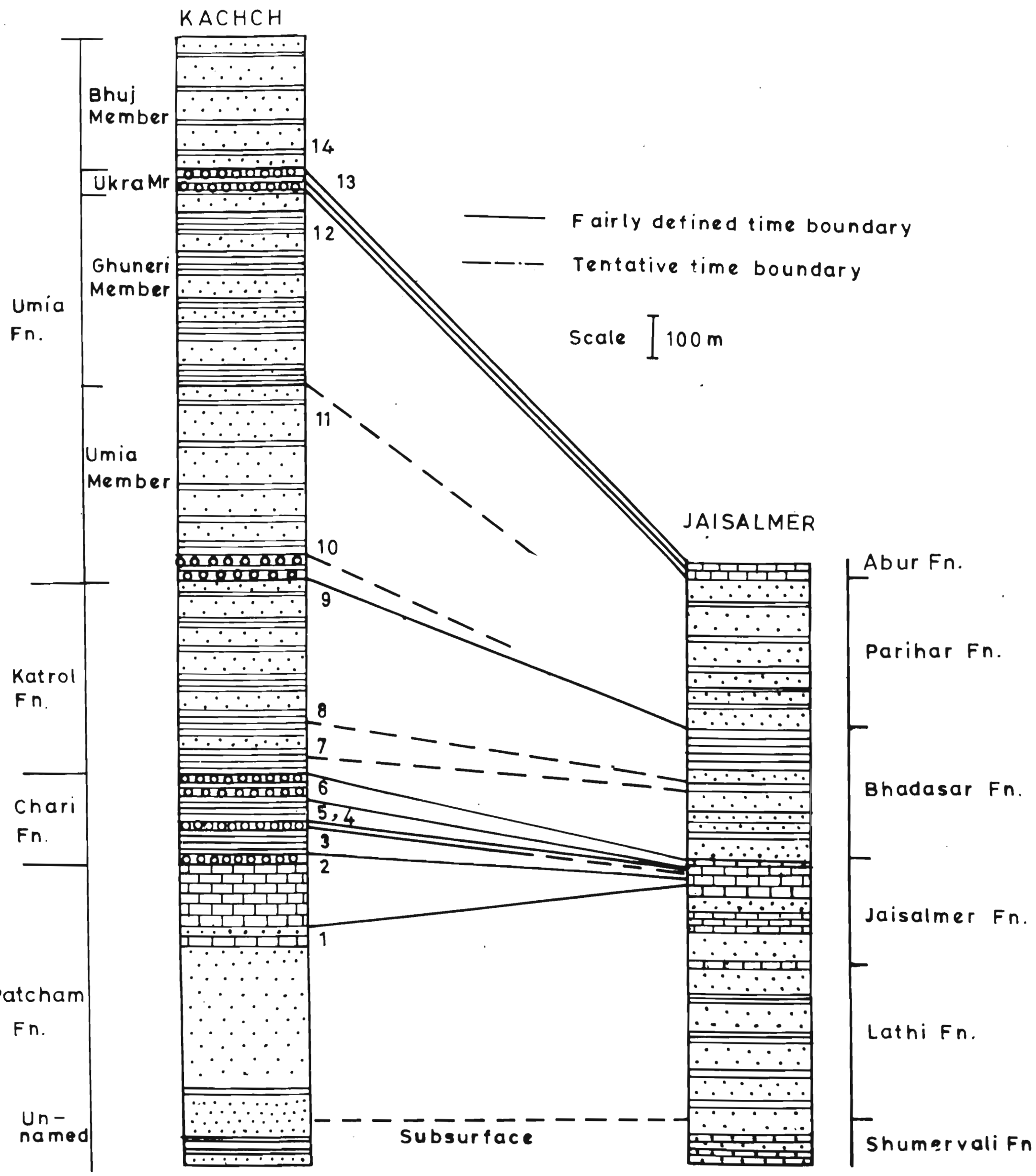


Fig. 2 Lithostratigraphic sequences of the Mesozoic rocks in Kachchh and Jaisalmer basins.

Formation as done by Biswas.

As discussed earlier (Krishna, 1983b) Katrol/Umia formational boundary is better defined and is easily recognizable inthe field than the 'Jhuran'/'Bhuj' boundary described on the basis of non-physical and rather abstract subjective characters.

AMMONOID HORIZON/ASSEMBLAGES AND TIME BOUNDARIES (Figs. 2 and 3; Tab. 3).

*Leptosphinctes* horizon (Upper Bajocian): Until quite recently the earliest difinite ammonids known from Kachchh belonged to the the Upper Bathonian/Lower Callovian that too from Mainland, when Singh *et al.* (1981) collected a single specimen indentfied as *Leptosphinctes* and index genus of Upper Bajocian from Patcham.

The *Leptosphinctes* horizon is underlain by about 70 m of exposed sediments, which so ar have not yielded any ammonoids or other datable fossil elements. However, regional stratigraphic frame-work in the India-Africa divergent plate area close to western India (Baluchistan, Salt Range, E. Africa, Madagascar etc.) shows the presence of Sinemurian through *Arietites* and *Oxynoticeras* in Baluchistan (Holland, 1909) and of Toarcian through *Bouleiceras* in Baluchistan (Holland, 1908) and also in Salt Range (Fatmi, 1977) which suggests the possible presence even of ealier stages inthe exposed part, particularly, since such presence has already been indicated in the subcrops on micro-floral evidence (Koshal. 1983).

*Micromphalites* - *Gracilisphinctes* - *Clydoniceras*-*Bullatimorphites* assemblage (Middle Bathonian): The

Table 3. Ammonoid assemblage and time boundaries in Mesozoic basius of Kachchh and Jaisalmer, W. India

| STAGE | KACHCHH | JAISALMER |
|---|---|---|
| Lower Albian | *Lemuroceras* | *Douvilleiceras* |
| Upper Aptian | *Australiceras* | *Epicheloniceras* |
| Lower Aptian | Radioactively dated 112 m.y. | Deshayesites |
| Hat.-Barrem. | Mega flora and palynomorphs | Megaflora and Palynomorphs |
| Barr.-Valan. | Trigonid bivalve species | " " |
| Upper Tithonian | *Virgatosphinctes-Micracanthoceras* | ? ? |
| Middle " | *Aulacosphinctoides-Hildoglochiceras* | *Virgatosphinctes* |
| Lower " | *Pachysphinctes-Katroliceras* | *Pachysphinctes* |
| Kimmeridgian | *Torquatisphinctes* | *Torquatisphinctes* |
| Middle Oxfordian | *Dichotomosphinctes* | ? ? |
| " " | *Mayaites maya* | *Mayaites* |
| Lower Oxfordian | *Peltoceratoides semirugosus* | ? ? |
| Upper Callovian | *Peltoceras athleta* | ? ? |
| Middle Callovian | *Collotia gigantea* | *Collotia gigantea* |
| " " | *Reineckeia anceps* | *Reineckeia anceps* |
| Lower Callovian | *Subkossmatia opis* | *Subkossmatia opis* |
| " " | *M. semilaevis* | *M. semilaevis* and *M. chariensis* |
| " " | *M. dimerus* | |
| Lowest Callovian-Upper Bathonian | *Macrocephalites triangularis* | *M. madagascariensis* |
| Middle " | *Micromphalites-Gracilisphinctes* | bivalves only |
| Lower " | ? ? | ? ? |
| Upper Bajocian | *Leptosphinctes* | bivalves only |
| Rhaet./Lias. | Palynomorphs only | Palynomorphs only |

Fairly well defined boundary, — — — — — Approximate boundry

next younger ammonoid assemblage has also been encountered in Patcham (Singh, Pandey and Jaitly, 1983) within 8 m of shales and oolites. Thick sands intervene between the *Leptosphinctes* below and the present horizon.

*Macrocephalites triangularis* assemblage (Upper Bathonian-Lowest Callovian): *M. triangularis* Spath, *M. madagascariensis* Lemoine, well over 50 years (Spath, 1927-33). Later investigations inother Mainland sections could not recover this assemblage, although recently Singh *et al.* (1983) mentioned the occurrence of *M. triangularis* Spath and *M. Madagascariensis*Lamoin together with several other species of *Macrocephalites* spread through 95 m of yellow to brown limestones with oolite and shale intercalations. They do not seem to have differentiated this large fauna into separate assemblages. Recently, the author and associates (1981-83 unpublished data) have collected the assemblage for the first time from precisely measured Jumara section, and have found it representing a distinct zone (up to bed D of the present author equivalent to bed 23* and 24 of Rajnath) as initially suggested by Spath (1927-33). The strata containing this assemblage in Jumara section are made up of highly recrystallised limestones overlying a seemingly rich coral-broyozoan reefoid complex. Spath (1927-33) had originally dated this assemblage as Upper Bathonian but Arkell (1956) redated it as lowest Callovian and

Since Rajnath's bed nos. 1 to 26 are in reverse order to normal order of superposition, equivalent numbers A to Z are also used here in order of superposition.

following him workers in India, Madagascar and East

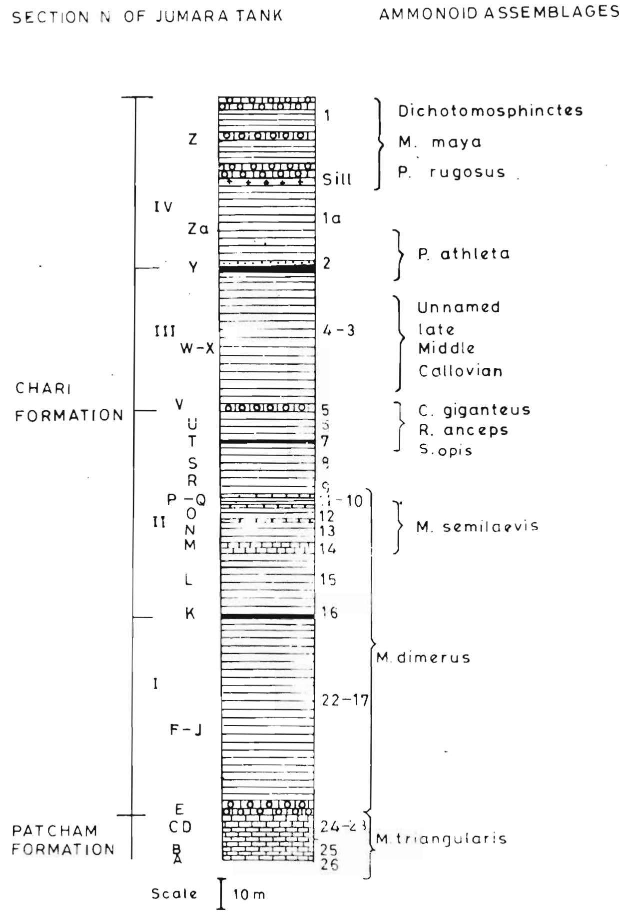


Fig. 3 Biostratigraphic zonation of the Jurassic sequence north of Jumara Tank based on ammonoid assemblages.

Africa equivocally assigned it to the lowest Callovian. The understanding was that the first appearance of *Macrocephalites* everywhere as in the Callovian stratotype in England signaled the start of Callovian. Recently Krishna *et al.* (1983) based on new information (Westerman pers. comm.) from Germany, New Guinea, Indonesia etc. in conjuction with first coccolith results from basal beds of Chari Formation in Jumara section suspected the lower limit to extend into Upper Bathonian. This is likely to have significant bearing on Bathonian/Callovian boundary not only in Kachchh but also in Europe and elsewhere. This assemblage is probably also indicated through doubtful loose fragments resembling *M. triangularis* Spath in the central (core) part of Jara dome (Krishna, 1981-83 unpublished field data).

The ammonoid assemblages identified within Chari Formation (Lower Callovian to Middle Oxfordian) are as follows:—

*M. dimerus* assemblage (early Lower Callovian): This ammonoid assemblage is composed of numerous macrocephalitin species viz. *M. dimerus* (Waagen), *M. formosus* (Sowerby) *M. chariensis* (Waagen), *M. transitorius* Spath etc. In most of the sections in Kachchh this assemblage is spread up in a large thickness of about 100 m. The main indices *M. dimerus*, *M. chariensis* and *M. formosus* appear at the base of Chari Formation (Bed E equivalent to bed 21 of Rajnath changed to bed 22 in Fig. 2) and ranges up to bed Q or bed 10 of Rajnath.

*M. semilaevis* assemblage (late Lower Callovian): This is neither a rich nor a well defined assemblage, and mostly overlaps with the uppermost part of *M. dimerus* assemblage. It is not clear as to which bed (M or N) marks the first appearance of *M. semilaevis* (Waagen) and which bed marks the extinction (bed Q or higher).

*Subkossmatia opis* assemblage (late Lower Callovian): Eucycloceratins particularly *S. opis* (Sowerby) are found in significant numbers immediately following the extinction of macrocephalitins on the lower side and prior to the full bloom of reineckein stock on the upper side. The assemblage comprises *S. opis* (Sowerby), *S. discoidea* Spath, *Idiocycloceras perisphinctoides* Spath etc.* Several species of *Indosphinctes* are found associated, and rare reineckeins (other than *R. anceps* group) also seem to have appeared. This assemblage is rich and very distinct and easily recognisable. It ranges through beds T and part of U equivalent to 7 & part of 6 of Rajnath in Jumara section. It is significant to note that this is the first assemblage composed mainly of Indo-East-African province (Krishna, 1983a) endemic elements at the generic level.

*Reineckeia anceps* assemblage (early Middle Callovian): *R. anceps* (Quenstedt), *R. indosabauda* Parona and Bonarelli and associated morphovariants make up this assemblage which is very rich, distinct and easily identifiable and ranges from beds U to V equivalent to beds 6 to 5 of Rajnath inJumara section. The first appearance of well known *R. anceps* also marks the Lower/Middle Callovian time boundary.

*Collotia gigantae* assemblage (late Middle Callovian): This horizon is only about 1 m thick but composed of rich *C. gigantea* Burquin and is restricted to uppermost part of bed V equivalent to 5 of Rajnath.

*Peltoceras athleta* assemblage (early Upper Callovian): This assemblage is characterised by many species of *Peltoceras* including *P. athleta* (Philips). Hitherto *P. athleta* (Philips) was supposed to be unrepresented in India. The author during field trips (1981-83) has collected number of *P. athleta* (Philips) together with other already discovered Kachchh species of *Peltoceras* from Jumara and Jara sections restricted in a small thickness. The presence of *P. athleta* (Phillips) is particularly significant since Spath's (1927-33) grouping of the Upper Callovian beds of Kachchh as Athleta beds has over the years received strong criticism from workers in Kachchh (Agrawal, 1957 and others). It is

* Rajnath's original bed 23 (craggy sandstones and brown shales) is possibly younger to bed 22 (cream coloured nodular limestone)although thought otherwise by him; their positions and numbers are changed accordingly in Fig. 3

suggested here to reinstate *P. athleta* Zone in Kachchh. The *Peltoceras athleta* assemblage (with or without *P. athleta*) is very distinct in majority of the Callovian sections in Kachchh.

Upper part of the purple shales immediately underlying the first oolitic band of the Dhosa Oolite Member is very poor or almost lacking in ammonoids, and represents the uppermost Callovian in Kachchh. The base of the Dhosa Oolite Member marked by the first oolitic band above the shales containing *P. athleta* assemblage in its lower part suggests to date the nearest approach to Callovian/Oxfordian boundary in Kachchh. It may be stated here that Agrawal's (56, 57, 81) dating of Dhosa Oolite Member as Callovian-Oxfordian is possibly due to slip in differentiating between late Lower Callovian to early Middle Callovian eucyclocertins and similarly looking Oxfordian *Paryphoceras*.

*Peltoceratoides semirugosus* assemblage (Lower Oxfordian): The first assemblage within Dhosa Oolite Member comprises several species of *Peltoceratoides*, *P. semirugosus* (Waagen) being quite common. The assemblage is very rich, distinct and easily recognisable.

*Mayaites maya* assemblage (Middle Oxfordian): This assemblage is mainly compsed of the species of the Indo-E. African endemic genera *Mayaites, Epimayaites, Dhosaites, Paryphoceras*. indicating growing faunal provincialism.

Perisphinctin assemblage (Middle Oxfordian): The assemblage in the topmost beds of the Dhosa Oolite Member is dominated by perisphinctins belonging to *Dichotomosphinctes*.

There is a sudden change in lithology from Oolitic limestones to shale sandstone alternations, which marks the Chari/Katrol formational boundary. This has been often interpreted as a disconformity on physical or paleontological considerations. Although it is somewhat difficult to precisely date the first ammonoid assemblage of Katrol Formation as Kimmeridgian or Lower Tithonian because of its endemic character and lack of well dated short ranging cosmopolitan elements, pre liminary cocolith studies (Jafar, pers. comm.) sugges the presence of Kimmeridgian in Katrol Formation. If that be so, time break if any involved at Chari/Katrol formational contact is of a short duration one, and Kimmeridgian may not be entirely missing. The ammonoid assemblages within the Katrol Formation are as follows:

*Torquatisphinctes alterniplicatus* assemblage (Kimmeridgian to Lower Tithonian): It is mostly made up of species of *Torquatisphinctes* in association of a few *Aspidoceras* particularly *A. acanthicum* (Oppel.) It may be noted that *Torquatisphinctes* is not exclusive to this assemblage but possiblv also occurs in the succeeding assemblage in the section E of Ler. (Fig. 4). Again the elements of the assemblage are mostly endemic

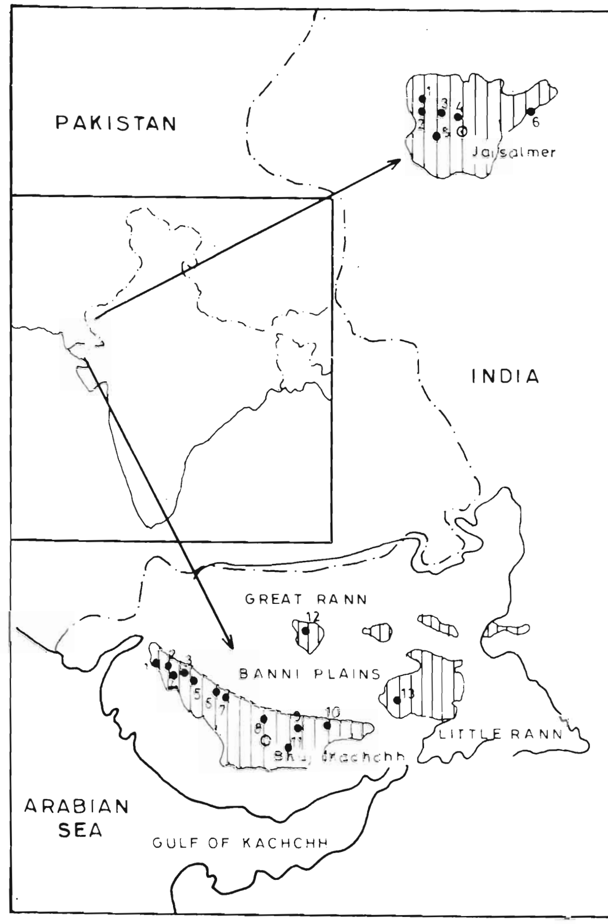


Fig. 4 Location of the Mesozoic Kachchh and Jaisalmer Basins.

to Indo-East-African faunal province.

*Katroliceras-Pachysphinctes* assemblage (Lower Tithonian): This rich assemblage is made up of the species of *Katroliceras* and *Pachysphinctes* almost in equal proportion in the section E of Ler. It is also endemic as the one below.

*Hildoglochiceras* assemblage (Middle Tithonian): Not very distinct, this assemblage is only known from Nara, Jara, Gajansar and east of Ler sections. It is mainly indicated by species of *Hildoglochiceras*, but few *Aulacosphinctoides, Subdichotomoceras* and rare *Virgatosphinctes* are also found associated.

There is substantial thickness of sediments above this assemblage which is largely lacking in ammonoids. The transition from Katrol to Umia is gradational both in Ler and Bhuj-Mandvi road sections; however the author (1983b) has suggested the base of the glauconitic sandstones between 16th and 17th km stone on the Bhuj-Mandvi Road as the Katrol/Umia boundary in eastern Kachchh. On the contrary Katrol/Umia formational contact is very explicit in western Kachchh at the base of the oolitic glauconitic green ammonoid bearing shales and marls indicating an easily identifiable Middle/Upper Tithonian time boundary.

The revised divisions within Umia Formation have been discussed earlier by the author (1983b) into Umia, Ghuneri, Ukra and Bhuj members in ascending order. The ammonoid assemblages within the Umia Formation are as follows:

*Viragatosphinctes-Micracanthoceras* assemblage (Upper Tithonian): The assemblage is indicated by *Micracanthoceras* associated with *V. densiplicatus* (Waagen).

The only other ammonoid horizon known from Umia Member is the recent recovery of a single septate one cm. diameter (early part of some ammonoid) at the base of the trigonid bearing sandstone. The trigonids have been best dated as early Lower Cretaceous (Berriasian-Valanginian) Spath (1935). The contact of the oolitic glauconitic ammonoid bearing green marls and the overlying trigonid bearing sandstone succession in the Lakhapar section indicates the nearest approach to Jurassic/Cretaceous boundary. The youngest trigonid horizon representing the top of the revised Umia Member is again a well expressed Umia/Ghuneri boundary. Further up, Ghuneri/Ukra lithostratigraphic contact in the Katesar nala section provides a broad suggestion (the only so far possible) of the Barremian/Aptian time bountary as based on the glauconite date from the base of the Ukra Member (Rajgopalan in Krishna, 1983b).

*Australiceras assemblage* (Upper Aptian): It is very distinct assemblage spread through brown grits indicating Upper Aptian age, and the Lower/Upper Aptian boundary is easily picked up at the first appearance of *Australiceras*.

*Lemuroceras-Cleoniceras* assemblage (Lower or early Middle Albian): This is the youngest ammonoid assemblage of Kachchh discovered only recently (Krishna et al., 1983 and Krishna, 1982, 1983b). It is represented by rare *Lemuroceras* and *Cleoniceras* in the uppermost horizons of Ukra Member west of Ghuneri. It is significant to note that this is the first definite evidence indicating the presence of Lower or early Middle Albian although unsubstantiated suggestions of the presence of Albian have been made earlier. The Ukra/Bhuj contact is easily picked up by the last trigonid bearing coquina with rare *Lemuroceras* indicating the top of Lower or early Middle Albian.

JAISALMER BASIN

Blanford (1877) and Oldham (1886) were the earliest to study the Mesozoic sediments of Jaisalmer. Oldham provided a five-fold lithostratigraphic scheme, which after appropriate corrections in accordance with the code of stratigraphic nomenclature has stabilised as I. Lathi Formation (Lower Jurassic), 2. Jaisalmer Formation (Bathonian to Oxfordian with doubtful Bajocian), 3. Bhadasar Formation (inclusive of Baisakhi Formation of Swaminath) Kimmeridgian to Middle Tithonian), 4. Parihar Formation (Upper Tithonian and Neocomian) and 5. Abur Formation (Lower Aptian to Lower or early Middle Albian). To these may be added the subsurface Shumervali Formation (Triassic) underlying the Lathi Formation at the lower side, subsurface Goru Formation (equivalent in part to Abur Formation) and Parh Formation in that order above the Parihar Formation on the upper side (Tables 1 & 2). Dasgupta (1975) has subdivided the individual Formations into members on the basis of his extensive field work. The entire succession with the exception of limestone dominated Jaisalmer and Abur units is made up of sandstones with interbeds of shales and clays. The limestone rich Jaisalmer Formation has been subdivided into 6 members: 1. Hamira Member, 2. 'Joyan Member', 3. 'Fort Member', 4. 'Bada Bag Member', 5. 'Kuldhar Member' nd 6. 'Jajiya Member' in ascending order. The first 5 divisions are in the name of Narayanan (in Dasgupta 1975) while the sixth Jajiya Member has been created recently by Kachhara and Jodhawat (1981). Krishna (1980a and 1983a) has recognised only two subdivisions within Jaisalmer Formation: namely Jaisalmer Member and Kuldhar Member. It may be emphasized here that the first 4 members are characterised by the uniform lithology of limestones and marls with interbeds of sandstones while the last two are distinguished by their oolitic lithology. Kachhara and Jodhawat (1981) have carved out Jajiya Member out of Kuldhar Member on Paleontological consideration not on physical characters. Moreover, the distinctive ammonoid fauna of 'Jajiya Member' has been known already through the works of Richterbernburg and Schot (1963) and Krishna (1979 and 1983a) and is not newly discovered. Since lithology of Baisakhi Formation which has been carved out of Bhadasar Formation by Swaminath (1959) is not much different from that of Bhadasar Formation (sensu Oldham, 1986) it is included here in Bhadasar Formation. In fact the entire unit is made up of sandstone/shale alternations with increasing sand content upwards and the sedimentation as revealed by the succession of ammonoid is more or less continuous. It is further significant that the subcrop succession (Dasgupta 1975) also does neither reflect any break nor any lithological differentiation within the composite Bhadasar Formation. Krishna (1983a) envisaged three divisions; 1. Rupsi Member, 2. Bhadasar Member and 3. Mokal member, while Dasgupta (1975) has in all 5 divisions in his Baisakhi and Bhadasar units.Bhadasar Formation is here considered to include all the 5 members (Tables 2 and 5).

There is some difference of opinion among the workers about the dating of Mesozoic units in Jaisalmer. Recently Kachhara and Jodhawat (1981) have tried to clarify the position with regard to Jaisalmer Formation. It may be stated here that the upper age limit of Jaisalmer Formation is fairly well stabilised Oxfordian in view of the presence of mayaitin ammonoids (Richter-bernburg and Schott 1963, Dasgupta 1975, Krishna 1975a, 1983a), althogh Datta (1983) has put it in Callovian. The lower limit of the unit as Upper Bathonian (Singh & Krishna 1969, Krishna 1983a) could be brought further down into Bajocian as suggested by Kachhara and Jodhawat (1981), however the bivalve evidence presented by them is only suggestive and not decisive. Bhadasar Formation (inclusive of Baisakhi) assigned as Kimmeridgian-Tithonian, although Datta (1983) considers it to be Oxfordian. Parihar Formation is broadly Neocomian on the indirect ammonoid evidence of ages from the underlying and overlying units. Abur Formation long considered to be Aptian (Spath, 1933, Richterbernburg & Schott 1963, Swaminath 1959, Dasgupta 1975 etc.) has been extended to Lower or early Middle Albian on ammonoid evidence (Krishna 1975b, 1980a, 1983a and 1983b).

AMMONOID ASSEMBLAGES AND TIME BOUNDARIES
(Figs. 2 & 3 and Table 3)

The Mesozoic lithostratigraphic units of Jaisalmer as indicated earlier show strong homotaxiality with similar units of Kachchh, however the succession is less thick and somewhat condensed in parts. The ammonoid assemblages are also not as rich as in Kachchh. The assemblage are:

*Macrocephalites madagascariensis* assemblage (Upper Bathonian): The assemblage is known only through a few specimens of *M. madagascariensis* Lemoine at the base of the Kuldhar Formation and it is coeval of *M. triangularis* assemblaqe of Kachchh.

*M. transitorius* (early Callovian assemblage: It is indicated through the co-existence of *M. chariensis* (Waagen), *M. semilaevis* (Waagen) and *M. transitorius* Spath. It is coeval to two successive Lower Callovian assemblages *M. dimerus* and *M. semilaevis* of Jumara (Kachchh). Further differentiation is not possible at present.

*Subkossmatia opis* assemblage (late Lower Callovian): This is the first rich and very distinct assemblage in the Kuldhar section of Kuldhar Member, and comprises *S. opis* (Sowerby), *S. discoidea* Spath and *I. perisphinctoides* Spath. The first appearance of *S. opis* (Sowerby) marks an easily identified time boundary.

*R. anceps* assemblage (early Middle Callovian): This is a rich and distinct assemblage indicated by *R. anceps* (Quenstedt), *R. indosabauda* Parona and Bonarelli and related reineckeins. The base of this assemblage or the first appreance of *R. anceps* (Quenstedt) reflects another time boundary also representing the Lower/Middle Callovian boundary in Jaisalmer.

*Collotia gigantea* assemblage (Late Middle Callovian): It is indicated by *C. gigantea* Burquin and related *Collotia* immediately above the reineckeins.

The above ammonoid assemblages correspond to a small thickness of 10 to 15 m of limestones and marls which are often oolitic. Further up another 6 m of succession is largely ammonoid lacking and so far no peltoceratins have been discovered. Based on stratigraphic position above the Middle Callovian and below the Oxfordian ammonoid bearing horizons it may be assigned Upper Callovian age.

*Mayaites maya* assemblage (Middle Oxfordian): This is the only ammonoid assemblage from Jaisalmer referable to Oxfordian. It is very rich and comparises *M. maya* (Sowerby) and other *Mayaites, Epimayaites, Dhosaites* and *Paryphoceras* etc.

Further up, in Bhadasar Formation only Rupsi Member and Bhadasar Member (= Kolar Dungar Member of Dasgupta, 1975) are found ammonoid bearing, and the ammonoid assemblages are as follows:

*Torquatisphinctes alterniplicatus* assemblage (Upper Kimmerdgian): This is the oldest ammonoid assemblage within Bhadasar Formation. Dominated by *T. alterniplicatus* (Waagen), this modest assemblage encloses many species of *Torquatisphinctes*, besides *Pachysphinctes bathyplocus* (Waagen), *P.* spp., *Tarmelliceras, Aulacosphinctes* etc.

*Pachysphinctes* assemblage (Lower Tithonian): It is made up several species of *Pachysphinctes*.

*Virgatosphinctes* assemblage (Middle Tithonian): It is made up of *V. densiplicatus* (Waagen), *V. communis* Spath and *Lithacoceras albulus* (Oppel).

The above 3 successive assemblages are mainly made up of virgatosphinctins which are under taxonomic revision.

No ammonoids have so far been discovered from any part of Parihar Formation. The ammonoid assemblages within Abur Formation are as follow:

*Deshayesites* assemblage (Lower Aptian): It is very rich and distinct and mainly comprises species of *Deshayesites* and related forms. The base of this assemblage marks the Parihar/Abur contact and is also the nearest approach to the Barremian/Aptian boundary in Kuchri section of Jaisalmer.

*Epicheloniceras* assemblage (Upper Aptian): This is only indicated by a single specimen of *Epicheloniceras*.

*Douvilleiceras* assemblage (Lower/Albian or early Middle Albian): This is a rich and distinct assemblage indicated by *D. mammilatus* (Schloth.), *D. inaequinodum* (Quenstedt), *Cleoniceras cleon* (d'Orbigny), *Lemuroceras, Hamites* etc.

DEPOSITIONAL ENVIRONMENT (Table 4 and 5)

Traditional thinking (which still largely prevails) holds the marine body fossil rich Jurassic part of the Mesozoic sediments of Kachchh as marine and the plant fossil-bearing but marine body fossil-lacking Lower Cretaceous part as non-marine/fluvial/deltaic (Blanford 1867, Wynne 1869, Spath 1933, Rajnath 1932 and 1942, Biswas 1971, 1977, 1982, Casshyap 1983 etc.).

Table 4. Synthesis of the Mesozic Lithostratigraphy in Kachchh Basin (Based on Previous lifenature and

| AGE | LITHOSTRAT. UNIT | | LITHOLOGY WITH GROSS PHYSICAL | MACROINVERTEBRATES |
|---|---|---|---|---|
| Upper Tithonian to Upper Albian | Umia Fn. | Bhuj Member | Medium to coarse sands with subordinate shales, large scale cross beds, several decimeter thick densely bio-turbated cycle cycle cappings. | Leaf impressions similar to Upper Gondwana. |
| | | Ukra Member | Glauconitic and colitic shales and sands, brown grits and coquina at the top. | Molluscs, belemnoids, brachiopods with fossil wood. |
| | | Ghuneri Member | sands with shale and silt alternations, carbonaceous shales and coal, medium to large cross beds, densely bioturbated sand cappings, small, large and interference ripples reflecting reactivation surfaces. | Leaf impressions similar to Upper Gondwana. |
| | | Umia Member | Ammonoid bearing colitic and glauconitic green marls, sands and shales in the lower part; trigonid bearing and other medium to coarse sands in the upper part. | Ammonoids *(Virgatosphinctes, Micracanthoceras)* etc. bivalves, trigonids and brachiopods. |
| Kimmeridgian to Middle Tithonian | Katrol Formation 450 m. | | Marls and sands at the base, flaggy sands in the Middle and coarse sands at the top with interbeds of shale; upwards coarsening cycles, sands increase in the system upwards; ferruginous concretions with occasional ammonoid in the nucleus in lower part; small and large cross beds including Hummocky Cross Stratification. | Poor in body fossils except in the lower part with abundant medium to large virgatosphinctin ammonoids; belemnoids and corals locally near the base at Jhuran river section; occasional wood & leaf. |
| Upper Bathonian to Upper Oxfordian | Chari Formation 240 m. | | Thinly laminated clays with intermittent hard sandy limestone and sandstone beds often oolitic; Dhosa Oolite at the top, golden oolite bands developed locally in lower and middle part at Jhura and Keera. Thin coarsening upwards cycles (marl, silt and sand in ascending order), wave ripple laminations in middle part with increasing sand and silt upwards and small cross beds; maroon, limonitic often oolitic hard bands reflect cycle capping with good body and trace fossil record. | Prolific, rich, diverse bivalves, ammonoids and brachiopods; ammonoids include macrocephalitins, reineckeins, peltoceratins, pseudoperisphinctins, mayaitins etc. corals, bryozoans, echinoids in lower and middle part at Keera reflecting reefal complex. |
| Bajocian or older to Upper Bathonian | Patcham Formation 360 m. | | Thick limestones often recrystallised with subordinate shale and sand interbeds in the upper part and thick sands with shale and clay intercalations in lower part with bioclastic peddle conglomerate at the base. | Corals, bryozoans, brachs and ammonoids in upper part at Jumara and Patcham; bivalves and rare ammonoids in lower part; body fossils poor in general. |

| TRACE FOSSILS | DEPOSITIONAL ENVIRONMENT | BOUNDARY AND SECTIONS |
|---|---|---|
| Intensely bioturbated sand horizons; *Thalassonoides, Skolithos, Chondrites, Ophiomorpha, Rhizocorallium, Aulichinites, Cylindrichnus* etc. common; borings in wood also observed. | Regressive shallow marine often above wave base tidal flat, rapid sedimentation with increased supply of terrigenous clastics, channel sands, estuarine and lagoonal influence interpreted locally (for Ghuneri & Bhuj units). Slow, clam, near wave base environment with fossil concentrations, low supply of terrigenous clastics, (for Ukra and Umia units). | Upper boundary in unconformable contact with Deccan Traps; lower boundary at the base of ammonoid bearing oolitic and glauconitic green marls and sands in Umia and Lakhapar sections |
| Densely bio-turbated sand horizons; *Ophimorpha, Thalassonoides, Aulichinites, Rhizocorallium Asteriacites, Laevicyclus, Planolites, Curvolithus, Scolicia,* etc. | Regressive shallow marine off shore mudand coastal sands interbedded with tidal flat deposits, fast sedimentation and increased supply of terrigenous clastics. | Upper boundary with Umia Formation as above; lower boundary indicated by the top of oolitic limestones of Dhosa Oolite Member easily recongizable all over Mainland. |
| Shales highly bioturbated, borings in wood and on hard grounds; *Chondrites, Gyrochorte, Ophiomorpha, Thalassonoides, Rhizocorallium* common. | Regressives shallow marine in upper part and transgressive in lower part, cyclic inner neritic shelf to subtidal or lower mud flat, low energy, protected with intermittent oceanic connections, Keera golden oolites high energy near reefal build-up; inner to mid neritic at Jumarawith fluctuations Dhosa Oolites high energy and slow deposition at Jumara and Keera. | Upper boundary as above; lower boundary at the base of shaly succession (base of bed 21 of Rajnath and bed F of the author at Jumara above the highly crystallised greyish white nodular limestone; at the contact of shales with underlying yellow limestones in the upper part of Patcham Formation at Patcham. |
| Horizontal trails common, few *Rhizocorallium,* in the **upper part** Lower sandy. sequence not e [illegible]ined for **trace fossils.** | Transgressive shallow marine, fluctuating, cyclic tidal flat in the lower part and intertidal in the upper part, subsidence and rapid sedimentation. | Upper boundary as above and lower boundary not exposed. |

The latter plant fossil-bearing part was also referred to as Upper or Coastal Gondwana (Sastry Acharya, Shah, Satsangi, Ghosh, Raha, Singh and Ghosh 1977, Datta Mitra and Bandhyopathyay 1983 etc.). Reappraisal of the depositional framework (Krishna et al., 1982, 1983, and Krishna 1982 and 1983b) based on modern facies interpretation and concepts of sedimentation suggests the deposition of the entire Mesozoic succession essentially by marine depositional processes, Howard and Singh (1985) and Bose, Shome, Bardhan and Ghosh (1986). The above reappraisal is based onthe presence of numerous wave and current built sedimentary structures, intensely bioturbated horizons, well recognised marine tracks, trails and burrows as well as borings in wood, thin glauconitic and oolitic horizons etc. It may be remarked that similar processes operate both in tidal and fluvial systems and the corresponding subenvironments also exhibit apparently similar gross facies characteristics, making the correct analysis often difficult. This is due to involvement of migrating channels in both the systems which results in cyclicity in sedimentation. However, the most significant revealing key features are the wave-built physical structures, strong bioturbation and biogenic marine inchnofossils found abundantly only in tidal system as in the case of Kachchh. The tidal currents are also mostly bidirectional in Kachchh (Cashyap 1983) in contrast to mostly unidirectional current pattern in the fluvial systems.

The entirely marine model in essence envisages sedimentation on an occasionally sheltered shallow tide affected shelf and adjoining tidal flats with localised estuarine and lagoonal influence (Krishna 1983b, Krishna *et al.* 1982, 1983 and Howard and Singh 1985). Kachchh was an E-W embayed basin. Modestly strong tidal range coupled with gentle bathymetric gradients seem to have resulted in extensive intertidal zone exposing present intertidal flats at the time of low tide of considerable dimensions on the pattern of bay of Fundy. Small rivers flowing in the intertidal depositional system resulting into estuaries. Several facies developed depending on the sediment source and wave and current energy. The single super sedimentational cycle started with a shallow transgressive sea on an almost peneplained granitic basement resulting in deposition of sediments of Patcham Formation (lower sandstones and upper carbonate part). Maximum depth (inner and mid neritic shelf) was reached during the Callovian part of Chari Formation. With upper part of Chari Formation onwards and several regressive shallow marine coarsening and growing upward cycles (Off-shore muds and coastal sands interbedded with tidal flat deposits, Krishna et alm., 1983).

The macro-invertebrate body fossils are found generally enriched in interspersed glauconitic and oolitic horizons which reveal comparatively slow sedimentation with decreased supply of terrigenous clastics. Their excellent preservation also indicates slow sedimentation, greater biological activity and reduced dynamic energy of the system. Bivalves (trigonids, astartids etc.) from the upper part of the Umia Member ('*Trigonia*' sandstone beds etc.) often are poorly preserved, disarticulated broken and abraded in contrast to the well preserved fossils of the glauconitic/oolitic horizons as discussed above suggest transportation, concentration and sorting on tidal flats by current waves and tidal channels.

Table 5 Synthesis of the Mesozoic Lithostratigraphy in Jaisalmer Basin.

| AGE | LITHOSTRATIGRAPHIC UNIT | LITHOLOGY WITH GROSS PHYSICAL STRUCTURES AND DEPOSITIONAL ENVIRONMENT | MACROINVERTEBRATES AND TRACE FOSSILS |
|---|---|---|---|
| Lower Aptian to Lower or early Middle Albian | Abur Formation 35 m. | Red to brown hard compact fossiliferous limestone with mosaic of yellow shell fragments, coquina bands, clay and marl intercalations, occasional thin intra-formational pebble conglomerates. Marine shallow inner to mid neritic shelf, intertidal slow and calm sedimentation. | Ammonoids *Deshayesites, Lemuroceras, Cleoniceras, Douvilleiceras, Hamites* etc., highly ornate trigonid and other bivalves, gastropods; trace fossils also observed. |
| Upper Tithonian to Neocomian | Parihar (=Pariwar) Formation 275 m. | Medium to coarse white and brown ferruginous sands with shale interbeds; medium to large wave ripples, large crossbeds; thick dense bioturbated horizons present. Regressive shallow marine often above wave base, rapid sedimentation, channel sands also present. | Leaf impressions, similar to Upper Gondwana; marine body fossils not reported so far, strong bioturbated horizons and trace fossils present however indicate high order biological activity. |

| | | | | |
|---|---|---|---|---|
| Kimmeri-dgian to Middle Tithonian | Bhadasar Formation 250 m. | Mokal Member<br>Bhadasar (=Kolar Dungar) Member<br>Rupsi Member<br>Lodarva Member<br>Baisakhi Member | Brown argillaceous sands with poorly preserved molluscs.<br>Several medium to coarse ferruginous sand horizons often gritty with interspersed marl bands with poorly preserved molluscs.<br>Lightcoloured shales with interspersed hard sandy bands having concretions, highly ammonoid bearing.<br>Shales with marl, silt and sand interca-lations often gypesous and carbonaceous.<br>Argillaceous and flaggy sands.<br>Regressive shallow marine. | Poor and badly preserved body fossils in general, Rupsi, Bhadasar and Mokal units ammonoid bearing mostly virgatosphinctins; locally belemnoids; brachiopods and coral banks developed at Bhadasar scrap reflecting small reefal build-up, occasional leaf impressions and fossil wood; bioturbated horizons and rich trace fossil record. |
| Bajocian to Oxfordian | Jaisalmer Formation 230 m. | Kuldhar Member<br>Jaisalmer Member | Yellow compact fossilliferous limestones and marls with several golden and brown oolitic horizons, and rich ammonoids.<br>Hard compact yellow coloured fossiliferous sandy limestones with interbeds of thick sandy limestones with interbeds of thick sandstones near the base, clay and marl intercalations common, rich bivalve and brachipods.<br>Mostly transgressive shallow marine intertidal to inner neritic shelf, high every oolites. | Rich diverse bivalves, brachiopods, echinoids, crinoids, althrough; belemnoids, nautiloids, and ammonoids exclusive to Kuldhar Member; ammonoids include macrocephalitins, eucycloceratins reineckeins, pseudoperisphinctins, mayaitins etc; Trace fossils also observed. |
| Lower Jurassic | Lathi Formation 350 m. | | Fine to coarse sands often ferruginous gritty to conglemeratic, sometiems calcareous with interbeds, of silt, clay and marlstone, conglomerate at the base.<br>Near shore transitional shallow marine. | Leaf impressions and fossil wood common; poor in macroinvertebrates. macroinvertebrates. |
| Triassic | Shumerwali Formation (In Subcrops only) | | Sandstones with subordinate shale interbeds.<br>? Shallow marine. | |

The marine body fossils devoid and plant fossil bearing part reflects faster rate of sedimentation and increased supply of terrigenous clastics. The sandstones were mostly deposited above the wave base often with tidal influences where wave built structures are common viz. wave ripples, interference ripples, medium and large cross beds including Hommocky Cross Stratification under high energy. Sandstone/shale alternations and sandstone cycle cappings with ichnofossils and bioturbation suggest low energy and high biological activity (Krishna *et at.* 1983). Thick apparently barren sandstone shale sequences (Ghuneri Member) occasionally contain thin clay and silt bands which show partially dissolved shells, shell impressions and cavities. The coal and carbonaceous shales represent coastal lagoons. The plant matter is mostly washed in from adjacent land areas and occurs together with or without marine fossils, but the enclosing sediments always show physical and biogenic structures indicative of marine processes. (Krishna *et. al.* 1983).

It is interesting to observe that the successive glauconitic/oolitic horizons gradually build up their lateral extent towards the coast until Oxfordian during the transgressive phase while those in the post-Oxfordian regressive phase show rapidly depleted lateral extent (Fig. 5). Since fossil concentrations often suggest near wave base depths, their above lateral migration represents the migration of the wave base of the single super-cycle. The youngest such horizon (Ukra Member) reflects an event towards the close of the regressive phase, instead

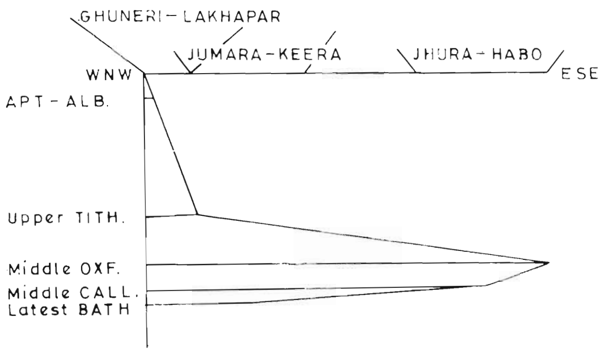


Fig. 5 Lateral extent of transgressive and regressive phases in the Kachchh Mesozoic Basins from Latest Bathonian to Aptian -Albian.

of representing the second Mesozoic transgression in Kachchh during Aptian as held previously (Biswas 1977 and others).

Jaisalmer and Bhadasar (inclusive of Baisakhi) and Abur units are marine shallow interspersed all through the section while the Lathi and Parihar sandy units require fresh interpretation of modern facies interpretation and concepts of sedimentation. Parihar Formation in particular evidences wave built physical structures viz. medium to large ripples, large cross beds and also several interspersed highly bioturbated sandstone horizons as in Umia Formation of Kachchh, and most likely reflect tidal flat depositional framework mostly above the wave base. However, a detailed composite investigation is required to precisely identify the sub-environments.

## HYDROCARBON POSSIBILITIES

Jaisalmer has remained a prospective basin since the beginning of ONGC oil exploration activities in mid-fifties. The initial expectations lay in the Paleogene carbonate sequences. In recent years oil and gas shows have been obtained in Middle Jurassic carbonates and Lower Cretaceous clastics in Jaisalmer (Datta, 1983).

The commercially hydrocarbon producing Bombay off-shore structures have lot in common with the Kachchh and Jaisalmer basins by way of structural framework, origin, marine shallow-shelf nature and linearity influenced by lineament tectonics. Moreover hydrocarbon pools are generally found associated with carbonaceous black shales and coal beds. There is also evidence of building up of high geo-thermal gradient from the beginning of Permian to close of Albian in the India-Africa divergent plate region (Dingle, 1981) close to the West Indian basins. There is every likelyhood that the desired heat regime was available to allow cooking and maturity of sediments for hydrocarbon generation during Mesozoic time.

Triassic and Lower Jurassic sand/shale succession of Shumervali (subcrops only) and Lathi Formation in Jaisalmer and Patcham Formation of Kachchh hold modest prospects for oil and gas entrapment (Datta 1983; Krishna, 1983) which however, require detailed investigation as to their precise depositional setting and geometry.

Thick carbonate dominated transgressive Bajocian-Oxfordian sediments of Jaisalmer Formation and upper part of Patcham Formation spread over 18 to 20 m.y. hold fairly good prospects. There are also evidences of small reefal build-ups at Keera, Jumara with possible extension west of the median high in Kachchh. With already proven alignment of linear oil and gas pools in Bombay off-shore tertiary carbonates, the western flank of the Mari-Jaisalmer arch and the subbasins west of the arch may prove rewarding. Kimmeridgian to Albian overall regressive often protected sand/shale alternations near coast shallow marine tidal flat, and lagoonal cyclic sequences hold some prospects although the wells drilled to date have gone dry. The succession of katrol and Umia units of Kachchh and Bhadasar and Parihar units of Jaisalmer also indicate development of dark, carbonaceous shale to coaly facies considered to be intimately associated with gas generating sediments. Extensive spread of Lower Cretaceous sand bodies (mostly tidal channel sands) and their possible extension in the subcrops and (off-shore Kachchh) seems to provide extremely favourable conditions for hydro-carbon accumulation prospects.

## CONCLUSION

The ammonoid based stratigraphy in the Mesozoic basins of Kachchh and Jaisalmer as built-up in the preceeding pages improves our understanding of time boundaries particularly west of the Median High and on the Mari-Jaisalmer arch. The Jumara, Lakhapar, Katesar and Chuneri sections in Kachchh and Kuldhar, Rupsi, Lanela, Bhadasar and Kuchri sections in Jaisalmer project forth as important sections for the understanding of Mesozoic stratigraphic set up. Further studies of the above sections should yield better refinement and precision of time boundaries. In spite of the somewhat time transgresive nature of many lithostratigraphic units, many major lithological changes are often regional and synchronus at least in the Kachchh Mainland. Macro and micro faunal/floral information available over the years from Mesozoic surface and subsurface sections of Kachchh and Jaisalmer also exemplify the globally proven phenomenon that the finest time resolution for most of Mesozoic is provided by the ammonoids.

The overall depositional setting presented here, highlights the crucial role of biogenic structures and mutlidisciplinary composite studies for facies understanding particularly in apparently barren clastic sequences.

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REFERENCES

AGRAWAL, S.K. 1956. Contribution a l'etude stratigraphique et Paleontologique du Jurassic de Kutch (Inde), *Ann. Centre et Document Pal.* Paris **19**: 188.

AGRAWAL, S.K. 1957. Kutch Mesozoic: A study of the Jurassic of Kutch with special reference to Jhura dome. *Jour Pal. Soc. Ind.* **2**: 119-130.

AGRAWAL, S.K. 1981, Kachchh Mesozoic: Some problems and recent contributions, *Recent Researches in Geology*. **8**: 399-413.

AGARWAL, S.K. & KACHHARA, R.P. 1977. Habo beds near Ler (Kutch): Pt.-2 Succession and fossil molluscs of the beds on the east of Ler. *Recent Researches in Geology*. **3**: 495-503.

AGRAWAL, S.K. & KACKER , A.K. 1978. Succession and fossil molluscs of the Jurassic rocks near Mouana, eastern Bela Island, district Kutch, Gujarat. *Recent Researches as Geology*. **4**: 482-492.

ARKELL, W.J. 1956. *Jurassic Geology of the World*, Oliver and Boyd, London. 806 p.

BADVE, R.M. & GHARE, M.A. 1978. Jurassic inchnofauna of Kutch-I. *Biovigyanam*. **4**(2): 125-140.

BISWAS, S.K., 1971. Notes on the geology of Kutch, *Quart. Jour. Geol. Min. Met. Soc. Ind.* **43**(5); 223-235.

BISWAS, S.K. 1977. Mesozoic rock-stratigraphy of Kutch, *Quart. Journ. Geol. Min. Met. Soc. Ind.* **49**(3&4): 1-52

BISWAS, S.K. 1980. Structure of Kutch-Kathiyawar region, Proc. 3rd *Ind. Geol. Congr.*: 225-272.

BISWAS, S.K. 1981. Basin framework, palaeoenvironment and depositional history of the Mesozoic sediments of Kutch basin, Western India. *Quart. Jour. Geol. Min. Met. Soc. Ind.* **53**(1 & 2): 56-85.

BISWAS, S.K. 1982. Rift basins in western margin of India and their hydrocarbon prospects with special reference to Kutch basin. *Bull. Amer. Assoc. Petr. Geol.* **66**(10): 1497-1513.

BISWAS, S.K. & DESHPANDE S.V. 1983. Geology and hydrocarbon prospects of Kutch Saurashtra and Narmada basins. *Petroleum Asia Journal*. **6**(4): 111-126.

BLANFORD, W.T. 1877. Geological notes on the great Indian desert between Sind and Rajputana. *Rec. Geol. Surv. Ind.* **10**; 10-21.

BOSE, P.K. SHOME, S. & GHOSH, g. 1986. Fac Mosaic in the Ghuner Member (Jurassic) of the Bhuj Formation, Western Kultch, India, *Sed. Goel.* **46** 293-309.

CASHYAP, S.M., ASLAM, M. & RAGHUVANSHI, A.K.S. 1983. Sedimentation and palaeographic model of Mesozoic basins of Gujarat (Abstract;, symp. *Petroliferous Baisns of India*, ONGC, Dehradun. **45**.

DASGUPTA, S.K. 1974. The stratigraphy of the west Rajasthan Shelf. *Proc. 4th Colloq. Ind. Micropaleont. Strat.*: 219-233.

DASGUPTA, S.K. 1975. A revision of the Mesozoic-Tertiary stratigraphy of the Jaisalmer basin, Rajasthan, Ind. *Jour. Earth Sci.* **2**(1): 77-94.

DATTA, A.K. 1983. Geological evolution and hydrocarbon prospects of Rajasthan basin, *Patroleum Asia Journal*. **6**(4): 93-100.

DATTA, B.N., MITRA, N.D. & BANDHYOPATHYAN, S.K. 1983. Recent trends in the study jof Gondwana basins of Peninsula and Extra-Peninsular India, *Petroleum Asia Journal*. **6**(4): 156-169.

DINGLE, R.V. 1981. Continental margin subsidence: A comparison between the east and west coast of Africa, *Geodynamics* Series **6**: 59-71.

ERMENKO, N.A. & NEGI, B.S. 1968. Tectonic map of India, **1**; 2000,000, Rep., ONGC, Dehradun.

FATMI, A.N. 1972. Stratigraphy of the Jurassic and Lower Cretaceous rocks and Jurassic ammonite from the northern areas of Pakistan. *Bull. Brit. Mus. Nat. Hist.* (Geol). **20**(7): 297-380.

FATMI, A.N. 1977. Neocomian ammonites from northern areas of Pakistan, *Bull. Brit. Mus. Nat. Hist.* (Geol.). **28**(4): 255-296.

HOLLAND, T.H. 1909. Liassic and Neocomian of Baluchistan. *Rec. Geol. Surv. Ind.* **38**: 25.

HOWARD, J.D. & SINGH, I.B. 1985. Trace Fossils in the Mesozoic sediments of Kachchh, Western India. *Paleogeogr. Paleoclim. Paleoc.* **52**: 99-122.

KACHHARA, R.P. & JODHAWAT, R.L. 1981. On the age of Jaisalmer Formation, Rajasthan, India. *Proc. 9th Ind. Collog. Micropaleont. & Strat.*: 235-247.

KANJILAL, S. 1978. Geology and Stratigraphy of the Jurassic rocks of Habo hill, district Kutch (Gujarat). *Proc. Nat. Acad.* Sci. Ind. **44**(1): 1-15.

KOSHAL, V.N. 1983. Differentiation of Rhaetic sediments in the subsurface of Kutch based on palynofossil (Abstract), *Symp. Petroliferous Basins of India*,: 43-44.

KRISHNA, J. 1975a. Biostratigraphy of the marine Mesozoic strata of Jaisalmer, Rajasthan (Abstract), *Sem. On Recent Advances in Pre-Camb. Geol. & Min. Dep. with special reference to Rajasthan, Sec., Younger Cover Rc oks, Udaipur*, p. 36.

KRISHNA, J. 1975b. New evidence on the *sem. on recent Advances in Precamb. Geol. & Min. Dep. with special reference to Rajasthan, Sec., Younger cover Rocks, Udaipur.* 36.

KRISHNA, J. 1979. Callovian-Tithonian ammonite stratigraphy and biogeography of Jaisalmer, India *The Syst. Ass. Symp., The Ammonoides*, York.35.

KRISHNA, J. 1980a. Uncoiled ammonoites of Middle Albian (Lower Cretaceous) age from Habbur Series, Jaisalmer, Rajasthan. *Jour. Pal. Soc. Ind.* **23-24**: 49-54.

KRISHNA, J. 1980b. Correlation of Callovian (late Middle Jurassic) — Albian (late Lower Creteceous) ammonoid and micro-fossil assemblages from sedimentary basins around the Indian Shield (abstract). *8th Ind. Collog. Micropaleont. Strat.* Baroda.9-10.

KRISHNA, J. 1982. New thoughts on the environment and paleogeography of the so-called coastal Gondwana (Lower Cretaceous) sediments of Kachchh, Western India (Abstract), *Internat. Sed. Congr.*, Hamilton. 29.

KRISHNA, J. 1983a. Callovian-Albian ammonoid stratigraphy and Palaeobiogeography in the Indian sub-continent with special reference to the Tethys Himalaya. *Him. Geol.* **11**: 43-72.

KRISHNA, J. 1983b. Reappraisal of the marine and/or 'mixed' Lower Cretaceous sedimentary sequences of India: Palaeogeography and the time boundaries. *Cretaceous of India, Ind. Assoc. Palynostrat.* 94-119.

KRISHNA, J. 1983. An overview of the Mesozoic Basins of Kachchh and Jaisalmer: Stratigraphy and Hydrocarbon Possibilities (Austr.), *Symp. Petro,iferopus Basins of India, Dehradun.* 42-43.

KRISHNA, J., SINGH, I.B. HOWARD, J.D. & JAFER, S.A. 1983. Implication of New data on the Mesozoic rocks of Kachchh, Western India. *Nature.* **305**; 790-792.

KUMAR, A. [&·&. Report on the occurrence of *Cyrochorte* and other bilobed trace fossils in the Jaisalmer Formation, Rajasthan, *Curr. Sci.* **48**(18): 87.

MITRA, K.C., BARDHAN, S. & GHOSH, K. 1979. A study of the Mesozoic stratigraphy of Kutch, Gujarat with special referenceto Keera dome, *Bull. Ind. Geol. Assoc.* **12**(2): 129-43.

OLDHAM, R.D. 1886. Preliminary notes on the geology of N. Jaisalmer. *Rec. Geol. Surv. Ind.* **19**(3).

PODDAR, M.C. 1964. Mesozoics of western India, their geology and oil possibilities. *Proc. 22nd Int. Geol. Congr.* pt. I; 126-143.

RAJNATH, 1932. A contribution to the stratigraphy of Cutch, *Quart. Jour. Geol. Min. Met. Soc. Ind.* **14**(4): 161-174.

RANJATH 1942. The Jurassic rocks of Cutch, their bearing on some problems of Indian geology. *Press. Address. 29th Ind. Sci. Congr.* **2**: 93-106.

RICHTERBERNBURG & SCHOTT 1963. Jurassic and Cretaceous at the western border of the Gondwana shield in India and the stratigraphy and oil possibilities. *Min. Res. Dev. Scr.* **18**(1).

SASTRY, M.V.A., ACHARYA, S.K., SHAH, S.C., SATSANGI, P.P., GHOSH, S.C., RAHA, P.K., SINGH, G. & GHOSH, R.N. 1977. Stratigraphic Lexicon of Gondwana Formations of India, Geol. Surv. Ind. *Misc. Publ.* **36**: 1-170.

SINGH, C.S.P., JAITLY, A.K. & PANDEY, D.K. 1981. First report of some Bajocian-Bathonian (Middle Jurassic) ammonoids and the age of the oldest sediments from Kachchh, western India, *Newslett. Stratigr.* **11**(1): 37-40

SINGH, C.S.P., PANDEY, D.K. & JAITLY, A.K. 1983. Discovery of *clydoniceras Blake and Gracilisphinctes* Buckman (Bathonian-Middle Jurassic ammonites) in Kachchh, western India, *Jour. Paleont.* **57**(4): 821-824.

SINGH, S.N. & KRISHNA, J. 1969. A preliminary note on the Mesozoic stratigraphy of Jaisalmer area, Rajasthan, *Jour. Pal. Soc. India,* **12**: 41-44.

SPATH, .F., 1927-33. Revision of the Jurassic cephalopod fauna of Kach (cutch), *Mem. Geol. surv. Ind. Pal. Ind.* N.S. **9**(2) 1p945.

SPATH, L.F., 1935. On the age of certain species of *Trigonia from the Jurassic rocks of Kach (Cutch), Geol. Mag.* **72**: 31-43.

SWAMINATH, J., 1959. General geology of Jaisalmer area, Rajasthan, Western India, *Min. Res. Dev. Ser.* **10**.

WAAGEN, W., 1873-75. The Jurassic fauna of Cutch, *Mem. Geol. Surv. Ind. Pal. Ind.* **1**(125): 1-247.

WYNNE, A.B. 1872. Memoir on thegeology of Cutch. *Mem. Geol. Surv.* Ind. **9**(1): 1-29.