

**CALLOVIAN-ALBIAN AMMONOID STRATIGRAPHY AND
PALAEOBIOGEOGRAPHY IN THE INDIAN SUB-CONTINENT
WITH SPECIAL REFERENCE TO THE TETHYS HIMALAYA**

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**HIMALAYAN GEOLOGY Vol. 11 pp 43—72
(Issued 1983)**

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ABSTRACT

The Callovian-Albian ammonoid stratigraphy in the Tethys Himalaya (Spiti-Malla Johar, Nepal and S. Tibet) is discussed in conjunction with that of Kachchh, Jaisalmer and Salt Range. The ammonoid succession is rather complete in the Tethys Himalaya but for the non-ammonitiferous Up. Callovian—Lr. Oxfordian and Kimmeridgian portion which is, probably, accounted for by unfriendly ecological conditions rather than signalling stratigraphic gaps. The Callovian-Oxfordian assemblages : 1. Lr. Callovian (macrocephalitins), 2. late Lr. Callovian-Mid. Callovian (eucylocerats, reineckeids etc.), 3. Up. Oxfordian (mayaitins), are much scantier in the Tethys Himalaya than in Kachchh and Jaisalmer. The Tithonian assemblages : 1. Lr. Tithonian (virgatosphinctins), 2. Mid. Tithonian (?) (virgatosphinctins, ataxioceratina etc.), 3. Up. Tithonian (berriasellids), are classically developed in the Tethys Himalaya but depleted elsewhere. The Lr. Neocomian ones (spiticeratins, olcostephanins etc.) are rich but developed only in Spiti-Malla Johar and Salt Range. The Aptian-Albian assemblages : 1. Aptian (deshayesitids, cheloniceratins, ancyloceratins etc.), 2. Lr. Albian-early Mid. Albian (douvreiceratins, hoplitids etc.), 3. late Mid. Albian-Up. Albian (brancoceratids) are respectively known from Nepal, Jaisalmer and Kachchh ; Jaisalmer ; and S. Tibet. The assemblages until near the close of the Jurassic have substantial index genera including many endemic ones (eucylocerats, mayaitins and virgatosphinctins) common to most of the Indian areas facilitating detailed correlation between the Tethyan and the West Indian areas irrespective of the facies difference.

INTRODUCTION

Ammonoids generally form an integral element of the marine Mesozoic sedimentary successions the world over. Since the early times of Von Buch, Quenstedt, Oppel, d'Orbigny, etc. these have been widely used as prime biostratigraphic indicators, regional and intercontinental correlation tools in view of their fast rate of evolution and wide and rapid geographic distribution,

considerable facies independence, preservational and collection potential, and ease of identification even in small fragments, requiring very little cleaning and preparation. Ammonoid distribution for stage and substage time intervals has been also employed towards the understanding of marine faunal provinces, faunal differentiation, marine connections, migration routes, etc. and finally, interpretation of plate tectonic/geodynamic models. Here is undertaken a limited exercise on similar lines taking upto date stock of ammonoid stratigraphy in different regions in the Indian subcontinent which were under the influence of the Tethys during the Callovian-Albian time interval. These regions are Spiti-Malla Johar, Nepal and S. Tibet in the Tethys Himalaya and Kachchh, Jaisalmer, Baluchistan, Salt Range etc. in the west and northwest of the Indian subcontinent.

The choice of the Callovian-Albian time interval for this exercise is in view of the facts that the pre-Callovian Jurassic sediments in the concerned regions are largely (Kachchh, Baluchistan, Salt Range, Nepal etc.) and sometimes entirely (Jaisalmer) devoid of ammonoids, and Aptian-Albian stages, the upper limit of this time interval, generally marks the culmination of ammonitiferous strata in Kachchh, Jaisalmer, Nepal, Salt Range, Baluchistan, Attock-Hazara except Spiti-Malla Johar where ammonoids disappear in early Neocomian and S. Tibet where they continue well up into Cretaceous. Among the different areas under consideration the ammonoid faunas of Kachchh, Baluchistan and Salt Range, and Spiti-Malla Johar have long been known respectively through the works of Spath (1924-33) and Uhlig (1903-10), although stratigraphic details of the ammonoids described by them were largely lacking. The last 25 years of studies on the stratigraphy and palaeontology of the Jurassic-Cretaceous strata in Kachchh (Agrawal, 1956, 1957; Agrawal and Kacker, 1978; Agrawal and Kachhara, 1977; Kanjilal, 1978), in Jaisalmer (Richter-Bernburg and Schott, 1963; Singh and Jai Krishna, 1969; Jai Krishna, 1975a, b, 1979a, b, 1980 and unpublished data), Spiti-Malla Johar (Shah and Sinha, 1974; Kumar *et al.*, 1977; Singh *et al.*, 1980; Jai Krishna, *et al.*, MS Salt Range (Fatmi, 1972, 1977), Nepal (Arkell, 1956; Bordet *et al.*, 1964; Helmstaedt, 1969; Mouterde, 1971) and S. Tibet (Mu *et al.*, 1973) have considerably added to the ammonoid faunas besides providing stratigraphic details largely lacking in earlier works. So much so that present state of our knowledge of these faunas, if not good, is worth an evaluation along lines attempted here.

Ammonoid stratigraphy of the Tethys Himalaya regions is discussed first to be followed by that of Kachchh, Jaisalmer and Salt Range in whose conjunction finally the entire data is quantitatively evaluated to depict relative similarity and differences of the faunas and implications of the same in favour

of a single marine faunal province.

AMMONOID STRATIGRAPHY

Tethys Himalaya

(I) **Spiti-Malla Johar**—The Callovian-Albian sediments belong to the following lithostratigraphic units in ascending order :

- | | |
|---------------------------------|-------------------------|
| 3. Guimal Sandstone Formation | (Hautervian—Barremian) |
| (300 m) | |
| 2. Spiti Shale Formation | (Oxfordian—Valanginian) |
| (200 m) | |
| 1. Ferruginous Oolite Formation | (Callovian) |
| (10 m) | |

Of these only 1 and 2 contain ammonoids and so of concern presently. Uhlig (1903-10), and Gansser (1964) have put an unconformity between these two units, whereas Kumar *et al.* (1977), Singh *et al.* (this seminar), Jai Krishna *et al.* (MS) have found favour with rather continuous sedimentation in Malla Johar area. These units together are about 210 m thick and are part of a folded sequence of argillaceous lithology, mostly black splintery shales and limestones. Jai Krishna *et al.* have broadly divided the Spiti Shale Formation into (A) Lower Member and (B) Upper Member on the basis of relative abundance of belemnoids in the former and of ammonoids in the latter. The Lower Member is a bit sandy and is largely devoid of ammonoids. Abundance, in it, of belemnoids suggests nearshore shallower part of the continental shelf as probable site of deposition. The Upper Member has yielded a rich ammonoid fauna, and Jai Krishna *et al.* have identified a succession of 5 ammonoid assemblages ranging in age from lowest Tithonian to Valanginian. Although the ammonoid collection studied by them did not include a single ammonoid either from belemniferous Lower Member or the underlying Ferruginous Oolite Formation, on the basis of earlier record from them (Blanford, 1865 ; Uhlig, 1903-10 ; Spath, 1933 and others) of Callovian ammonoids from the Ferruginous Oolite Formation and Oxfordian ammonoids from the Lower Spiti Shale Formation, at least three ammonoid assemblages (meagrely known) belonging respectively to early Lower Callovian, late Lower-Middle Callovian and Oxfordian are easily discernible. Kimmeridgian is, in view of the absence of definite ammonoids of this stage, considered to be made up of belemniferous portion. Singh and Kumar (1978) have described Callovian-Oxfordian benthonic foraminiferal assemblage from the lower part, and

Jain *et al.* (1978) have described definite Kimmeridgian dinoflagellate assemblage from the beds immediately underlying the upper ammonitiferous division of Spiti Shale Formation. On the whole Callovian-Albian ammonoid assemblages could be summarised as follows (based on Oppel, 1863 ; Blanford, 1865 ; Uhlig, 1903-10 ; Jai Krishna *et al.*, MS).

1. *Macrocephalites* assemblage (early Lower Callovian) : It comprises *Macrocephalites triangularis* Spath, *Dolikephalites flexuosus* Spath, *Macrocephalites macrocephalus* (Schlotheim), *Macrocephalites kitchini* Uhlig, *Macrocephalites lamellosus* Waagen, etc.

2. *Reineckela-Grossouvria* assemblage (late Lower Callovian-Middle Callovian) : It comprises *Reineckela* sp., *Reineckelites waageni* Till, *Grossouvria propinquus* Uhlig, *Distichoceras* (*Bonarelia*) cf. *bicostata* (Stahl), etc.

3. *Mayaites* assemblage (Oxfordian) : It comprises *Mayaites* sp. cf. *M. maya* (Sowerby), *M. waageni* (Uhlig), *Mayaites kitchini* (Uhlig), *Epimayaites* sp., *Prograyiceras grayi* (Spath), *Grayiceras nepalensis* (Gray), *Grayiceras* (*Prograyiceras* ?) *koenini* (Uhlig).

④ *Torquatisphinctes-Aulacosphinctoides* assemblage (Lower Tithonian) : It comprises *Torquatisphinctes* sp. cf. *T. alterneplicatus* (Waagen), *T. spp.*, *Aulacosphinctoides uhligi* Spath, *A. infundibulum* Uhlig, *A. chidamensis* Uhlig, *Aulecosphinctes inoptychus* Uhlig, *Gymmodiscoceras acucinctus* (Blanford), *Uhligites* spp., *Subdichotomoceras* (or *Katroliceras* ?) sp.

5. *Hildoglochiceras-Virgatosphinctes* assemblage (Middle Tithonian) : It is represented by *Hildoglochiceras kobelli* (Oppel), *Virgatosphinctes densipllicatus* (Waagen), *V. krafftii* Uhlig, *V. pompeckji* Uhlig etc.

6. *Himalayites-Corongoceras-Aulacosphinctes* assemblage (early Upper Tithonian) : It consists of *Himalayites* cf. *seideli* (Oppel), *H. ventricosus* Uhlig, *Corongoceras* spp., *Aulacosphinctes morekianus* Uhlig, *A. sp.*, *Virgatosphinctes multifaciatus* Uhlig, *Kossmatia* aff. *tenuistriata* Uhlig, *Parabolicseratoides* sp. cf. *P. mutilis* (Oppel), etc.

7. *Blanfordiceras* assemblage (late Upper Tithonian) : It mainly comprises species of *Blanfordiceras wallichi* Gray group *B. wallichi* Gray, *B. subquadratus* (Uhlig), *B. rotundidoma* Uhlig, *Haploceras* sp., *Substeuroceras* sp., etc.

8. *Neocosmoceras-Distoloceras* assemblage (Berriasian-Valanginian) : It comprises *Boehmiceras boehmi* (Uhlig), *B. asseni* (Boehm), *B. middlemissi* (Uhlig), *B. celebrant* (Uhlig), *Pterolytoceras exoticum* (Oppel), *Bochianites* sp., *Spiticeras* sp., *Neocomites* sp., *Odontodiscoceras* sp., *Neocosmoceras subradiatus*

(Uhlig), *N. octagonus* (Strachey), *N. acanthicus* (Uhlig), *N. hundesianus* (Uhlig), *Distoloceras* sp., *Olcostephanus* spp., *Rogersites* sp., etc.

(Detailed checklist of ammonoids from Spiti-Malla Johar area is given in Uhlig, 1903-10).

(II) **Nepal**—The Callovian-Albian sediments in Nepal belong to the following stratigraphic units :

- | | | |
|--|---|--|
| 3. Chuck Formation
(800 m) | { | 3(2) Dzung Sandstone Member
(Lower Aptian) (650 m) |
| | | 3(1) Kagbeni Sandstone Member
(Hautervian-Barremian)
(150 m) |
| 2. Spiti Shale Formation
(500 m) | | (Oxfordian-Valanginian) |
| 1. Ferruginous Oolite Formation
(5 m) | | (Lower and Middle Callovian) |

Of these 1, 2, and 3(2) are ammonitiferous. Almost all the workers on Nepalese sediments (Bordet *et al.*, 1964 ; Helmstaedt, 1969 ; Mouterde *et al.*, 1971) recognise an unconformity between the Ferruginous Oolite Formation and Spiti Shale Formation on the basis of ammonoid fauna as well as field evidences. These two units in Nepal have similar lithologic characters as in Spiti-Malla Johar, representing the extension of the type area sediments in Nepal. Definite Kimmeridgian ammonoids are also missing in the Nepalese sections, but the succession appears to be largely continuous. Sediments are part of a folded sequence. The Kagbeni Sandstone Member overlies the Spiti Shale Formation and is continental containing the typical Upper Gondwana *Ptilophyllum* flora. The Dzung Sandstone Member is again marine and contains Aptian ammonoids. Summing up, the following ammonoid assemblages seem to be present within the different stratigraphic units of Nepal (based on Arkell, 1956 ; Bordet *et al.*, 1964 ; Helmstaedt, 1969 ; Mouterde, 1971) :

1. *Macrocephalites* assemblage (early Lower Callovian) : This assemblage is very meagrely known. So far known ammonoids from this assemblage are *Macrocephalites formosus* Waagen and *M. (Indocephalites) chrysolithicus* Waagen.

2. *Grossouvria-Indosphinctes* assemblage (late Lower and Middle Callovian) : It is represented by *Indosphinctes urbanus* Spath, *Grossouvria calloviense* (Loczy) and *Lunuloceras* sp.

3. *Mayaites* assemblage (Oxfordian) : It comprises *Mayaites transiens*

(Waagen), *Epimayaites* gr. *falcoides* Spath, *Kranaosphinctes indogermanus* Waagen, *Ariesphinctes* gr. *helena* de Riaz, *Epimayaites waageni* Spath, *Prograyiceras grayi* Spath, *Orthosphinctes* sp., *Peltoceratoides* sp., *Grayiceras nepalensis* (Gray) and *Alligaticeras obliqueplicatum* Waagen.

4.) *Aulacosphinctoides-Katrolliceras* assemblage (Lower Tithonian) : This assemblage is fairly rich and distinct. It comprises *Katrolliceras pottingeri* Sowerby, *Aspidoceras unispinosum* (Quenstedt), *A. (Pseudowaagenia) microplum* (Oppel), *Aulacosphinctoides* sp. cf. *A. torquatus* (Sowerby), *Katrolliceras waageni* Spath, *A. radialecostus* (Steiger), Simocertinae gen. et sp. nov. indet., *Lemencia?* sp., *Aspidoceras* sp. cf. *A. eumicrophalum* (Steur), *Subplanites nepalensis* Helmstaedt, *S.* sp., etc.

5. *Virgatosphinctes-Himalayites-Blanfordiceras* assemblage (Middle and Upper Tithonian) : Although precise stratigraphic details of this fauna are yet not available, it indicates the presence of 2 or even 3 successive assemblages which appear to be mixed up. It mainly comprises species of the genera *Virgatosphinctes* *(6), *Aulacosphinctoides* (7), *Kossmatia* (3), *Parabolicseras* (7), *Parabolicseratoides* (1), *Himalayites* (3), *Blanfordiceras* (7), etc. The important species are *V. rotundidomus* Uhlig, *V. kagbeniensis* Helmstaedt, *Aulacosphinctes* sp. cf. *A. torquatus* (Sowerby), *A. morekianus* (Oppel), *Substeyroceras uhligi* Helmstaedt, *Corongoceras lotenoense* Spath, *Kossmatia tenuistriata* Uhlig, *Parabolicseras sabineanus* (Oppel), *Parabolicseratoides* sp. cf. *P. mutilis* (Oppel), *Himalayites* aff. *seideli* (Oppel), *Uhligites griesbachi* (Uhlig), *Blanfordiceras wallichi* Gray, *B. rotundidoma* Uhlig, etc.

6. *Berriasella-Boehmiceras* assemblage (Berriasian-Valanginian) : Helmstaedt (1969) on the basis of the presence of *Berriasella* sp. cf. *B. callisto* (d'Orbigny), *B.* sp., *Negrelliceras* sp., and *Thurmanniceras* sp. recognised the presence in Nepal of Berriasian and Valanginian stages of Lower Cretaceous. In addition *Pterolytoceras* sp. cf. *P. exoticum* (Oppel) and species of *Boehmiceras* are here considered to be also belonging to Berriasian-Valanginian rather than late Upper Tithonian.

7. *Deshayesites-Chelonicerases-Tropaem* assemblage (Aptian) : This assemblage, although meagre and depleted, distinctly represents the presence of Aptian stage. It comprises *Aconeceras?* sp., *Tropaem australe* Moore, *Deshayesites?*, *Prodeshayesites* sp., *Sanmartoniceras trautscholdi* Sinz., and *Chelonicerases meyendroffi* d'Orbigny.

(III) **S. Tibet (Mt. Jolmo Lungma Region)**—The Callovian-Albian sediments in the Mt. Jolmo Lungma region and neighbourhood on Nepal-China border belong to the following lithostratigraphic units :

* Number in paranthes after the generic name refers to the number of species.

- | | |
|--|---------------------------------|
| 3. Lower Formation (of Kangpa Group)
(1200 m) | (Valanginian-Coniacian) |
| 2. Menkatun Formation
(360 m) | (Tithonian) |
| 1. Upper Member (of Niehnieh
Hsuingle Formation)
(5 m) | (Lower and Middle
Callovian) |

All the above three units are ammonitiferous, but unfortunately the ammonoid fauna is little known yet. According to Mu *et al.* (1973) the ammonoids indicate the presence at least of the following assemblages in ascending order :

1. *Macrocephalites* assemblage (early Lower Callovian) : The genera *Macrocephalites* and *Kamptokephalites* are present in this assemblage.
2. *Haploceras-Virgatosphinctes* assemblage (Upper Tithonian).
3. *Neohoploceras* assemblage (Valanginian).
4. *Dipoloceras-Mortoniceras* assemblage (late Middle and Upper Albian).

The above 3 assemblages are recognised by the genera after which they are named. Details of the above assemblages and checklist of ammonoids from Mt. Jolmo Lungma region of S. Tibet are yet not available for evaluation. The fauna is presently under investigation by the Chinese palaeontologists. But whatever is known so far clearly indicates the presence of the Tethyan ammonoid elements already well known in Spiti-Malla Johar and Nepal, western and northwestern regions of the Indian subcontinent.

Western India

(IV) **Kachchh**—The Callovian-Albian sediments in Kachchh belong to the given stratigraphic units on page 50.

All the above units contain ammonoids. The Callovian (particularly Lower Callovian) is very rich and very well developed. The succession has been referred as 'expanded' in view of the comparatively much thicker sediments, and is considered as a reference for detailed zonation based on ammonoids. But so far except for Spath's (1933) hypothetical and impractical ammonoid zones, later workers on these ammonitiferous sediments (Agrawal, 1957 and others) have failed to identify in this region his detailed European zones and subzones. Taxa names in this *Macrocephalites* assemblage here have been revised in a view of Thierry's (1978) exhaustive treatise on the revision of the genus *Macrocephalites* Zittel. It may be noted that Thierry

4. Ukra Formation (20-25 m)		(Aptian)
3. Umia Formation (525 m)	{ 3(5) Barren Member { 3(4) Trigonina Member { 3(3) Barren Member { 3(2) Umia Ammonite Member { 3(1) Barren Shale Member	(Valanginian) (early Upper Tithonian)
2. Katrol Formation (750 m)		(Lower and Middle Tithonian)
1. Chari Formation (inclusive of Dhosa Oolite Member) (455 m)		(Callovian- Oxfordian)

recognises only two genera *Macrocephalites* Zittel and *Kamptokephalites* Spath in the subfamily Macrocephalitinae, bringing all other genera and subgenera into their synonymy. The present author also was finding it difficult in correctly interpreting the closely resembling genera and species erected by Spath in his work on macrocephalitins from Jaisalmer, and welcomes Thierry's findings. The late Lower and Middle Callovian and Upper Callovian stages are indicated respectively by eucycloceratins, reineckeids, etc. and peltoceratins. The Oxfordian is represented by a rich mayaitin assemblage (Upper Oxfordian) species of *Peltoceratoides* Spath (Lower Oxfordian). Definite Kimmeridgian ammonoids are yet not known, although the passage from Oxfordian to Lower Tithonian in different stratigraphic sections appears to be normal. It is also worth noting that the Kachchh Jurassic sediments are much thicker and the facies is predominantly near—shore littoral, infraneritic and epineritic. Oolitic lithology is prominently intercalated throughout the Callovian-Oxfordian. Bands of golden oolite at or near the base of early Callovian sediments and Dhosa Oolite Member at the top are broad marker horizons. It is a transgressive facies in the Callovian whereas the Tithonian indicates a regressing facies. The Callovian-Albian ammonoid assemblages of Kachchh could be summarised as follows (based on Waagen, 1873-75 ; Spath, 1924-33 ; Agrawal 1957 and Jai Krishna, unpublished data) :

1. *Macrocephalites* assemblage (early Lower Callovian) : This is further split in two successive subassemblages : (a) *Macrocephalites triangularis* assemblage (basal Callovian) and (b) *Macrocephalites diadematus* assemblage (early Lower Callovian). The former is characterised by different groups of species of the genus *Macrocephalites* (in the sense of Thierry, 1978) which are group of *M. subtrapezinus* Waagen including both its dimorph

microconch [= *Kamptokephalites subtrapezinus* (Waagen)] and dimorph macroconch *M. transitorius* (Spath) [= *Indocephalites transitorius* Spath], group of *M. formosus* (Sowerby) including its transient *M. triangularis* Spath [= *M. triangularis* Spath] and group of *M. macrocephalus* (Schlotheim) including its subspecies *M. macrocephalus macrocephalus* Thierry and *M. macrocephalus subcompressus* Spath [= *Dolikephalites subcompressus* Spath] and macroconch *M. madagascariensis* Lemoine. The latter subassemblage is represented by *M. semilaevis* Waagen [= *Nothocephalites semilaevis* (Waagen)], *M. chariensis* Waagen, *Macrocephalities diadematus* Waagen, *Kamptokephalites dimerus* Waagen, *Kamptokephalites habyensis* Spath and *K. magnumbilitatum* (Waagen).

2. *Subkossmatia-Idiocycloceras-Reineckeia* assemblage (late Lower and Middle Callovian): It mainly comprises species of the genera *Subkossmatia* (5), *Idiocycloceras* (3), *Reineckeia* (9), *Choffatia* (18), *Grossouvria* (11), *Subgrossouvria* (10), *Kinkelinicer* (9), *Indosphinctes* (11), *Obtusicosites* (7), *Hubertoceras*, etc. The characteristic species in this assemblage are *Subkossmatia opis* (Sowerby), *S. discoidea* Spath, *Idiocycloceras perisphinctoides* Spath, *Reineckeia indosabauda* Parona and Bonarelli, *Indosphinctes patina* Spath, *Kinkelinicer kinkelini* (Dacque), *Hubertoceras mutans* (Waagen), etc.

3. *Peltoceras* assemblage (Upper Callovian): It comprises *P. athleta* (Philips), *P. kachhense* Spath, *P. diviseforme* Waagen, *P. ponderosum* (Waagen), etc.

4. *Peltoceratoides* assemblage (Lower Oxfordian): It comprises *P. semirugosus* (Waagen), *P. propinquus* (Waagen), *P. indicus* Spath, etc.

5. *Mayaites* assemblage (Upper Oxfordian): It mainly comprises species of the genera *Mayaites* (9), *Epimayaites* (13), *Paryphoceras* (5), *Dhosaites* (3), *Prograyiceras* (2), etc. The characteristic species are *M. maya* (Sowerby), *M. obesus* Spath, *E. transiens* (Waagen), *E. evolutus* Spath, *E. excentricus* Spath, *E. falcooides* Spath, *P. badiense* Spath, *D. elephantoides* Spath, *Prograyiceras graji* Spath, etc.

6. *Torquatisphinctes-Katrolliceras-Subdichotomoceras*-assemblage (Lower Tithonian): It comprises species of the genera *Torquatisphinctes* (13), *Pachysphinctes* (11), *Katrolliceras* (12), *Aulacosphinctoides* (6), *Subdichotomoceras* (5), *Aspidoceras* (14), *Hyboniticeras* (5), *Lithacoceras* (3), *Hildoglochiceras* (6), *Virgatosphinctes* (6), *Aulacosphinctes* (1), etc. Among the most characteristic and common forms are *T. alterneplicatus* (Waagen), *T. torquatus* (Sowerby), *P. major* Spath, *P. bathyplocus* (Waagen), *K. pottingeri* (Sowerby), *K. katrolense* (Waagen), *K. waageni* Spath, *S. sparsiplicatum* (Waagen), *H. beckeri* (Neumayr), *H. hilderbrandti* (Beyrich), *A. acanthicum* (Oppel), *A. longispinum* (Sowerby), *Lithacoceras indicum* Spath. This assemblage in Kachchh

could be further split and spread up into two successive subassemblages : *T. alterneplicatus*-*A. acanthicum*-*H. beckeri* and *Katrolliceras*-*Sudichotomoceras*-*Aulacosphinctoides*.

7. *Hildoglochiceras*-*Virgatosphinctes* assemblage (Middle Tithonian) : It is neither very rich nor distinct, and is indicated by *H. kobbeli* (Oppel), *V. densiplicatus* (Waagen), etc., however, many workers prefer to unite it with the next younger assemblage.

8. *Virgatosphinctes*-*Micracanthoceras*-*Umiates* assemblage (Upper Tithonian) : This assemblage is not very rich and it appears that ammonoids are gradually disappearing from the Kachchh scene. It comprises *U. minor* Spath, *M. rajnathi* Spath, *M. brightoni* Spath, *M. micracanthus* (Oppel), *V. spp.*, etc.

9. *Chelonicerases*-*Australiceras* assemblage (Aptian) : It is again either depleted or yet not fully known. It consists of *Chelonicerases* sp. aff. *C. martini* (d'Orbigny), *Tropaeum australis* (Moore), *Australiceras australe* (Moore), *Deshayesites deshayesi* (d'Orbigny) and *Colombiceras waageni* Spath.

V. **Jaisalmer**—The Callovian-Albian sediments of Jaisalmer belong to the following stratigraphic units (modified after Singh and Jai Krishna, 1969 ; Jai Krishna, 1975a, b, 1979a, b, 1980). The author has preferred to retain long prevalent names given by Oldham (1886) with slight adjustments in their boundaries :

4. Habur (=Abur) Formation (35 m)		(Lower Aptian-early Middle Albian)
3. Parihar Formation (270 m)		(Neocomian)
2. Bhadasar (=Bedesir) (180 m)	{ 2(3) Mokal Member (Upper Tithonian) 2(2) Bhadasar Member (Lower Tithonian) 2(1) Rupsi Member (Kimmeridgian ?- lowest Tithonian)	
1. Jaisalmer Formation (300 m)		{ 1(2) Kuldhar Member (Callovian- Oxfordian) 1(1) Jaisalmer Member (Bathonian)

Among these 1(2), 2(1), 2(2) and 4 are ammonitiferous. The ammonoid assemblages throughout the succession are quite rich and distinct but to a lesser degree than in Kachchh. The Jurassic and Cretaceous ammonoids of

Jaisalmer for a long time were little known, and have received attention only during the last 20 years by Richter-Bernburg and Schott (1963), Singh and Jai Krishna (1969), Jai Krishna (1968, 1975a, b, 1979a, b, 1980 and unpublished data). The thickness of the Callovian sediments in Jaisalmer is markedly less than Kachchh, although the facies here too is coastal littoral, infraneritic to epineritic. The dips are low (2° to 4°) towards north, west and northwest and the sediments are structurally almost undisturbed except for a few normal gravity faults. The strata correspond to two marine incursions during the Mesozoic period, one in Bathonian and the other at the advent of Aptian, with Neocomian continental Parihar Formation intervening in between. The Jaisalmer shelf, it may be noted, appears to behave as an independent undisturbed structural unit in contrast to highly disturbed sediments of neighbouring Kachchh, Baluchistan and Salt Range regions. Probably the Jaisalmer basin was in the bay type of shelf shielded on either side by the stable original uplifts or 'highs' of Delhi age. An alternative explanation could be that the Jaisalmer shelf region was comparatively farther away from the margin of the Indian plate during the Mesozoic while Kachchh, Baluchistan, Salt Range, etc. were in the immediate neighbourhood of the Indian plate margin or other major fracture zones. Ammonoid assemblages of Jaisalmer are as follows :

1. *Macrocephalites* assemblage (early Lower Callovian): As in Kachchh this assemblage is divisible into two ; (a) Zone of *M. subtrapezinus* and *M. subcompressus* (Jai Krishna, 1979) and (b) Zone of *M. semilaevis* and *M. chariensis* Waagen. The former one is represented by respectively the macroconchs of *M. subtrapezinus* Waagen (= *M. madagascariensis* Lemoine) and *M. macrocephalus subcompressus* Waagen (= *Indocephalites transitoriae* Spath). The assemblage is scanty, although future search is expected to add to the number of ammonoid species in the assemblage. The latter is represented by *M. semilaevis* Waagen and *M. chariensis* Waagen.

2. *Subkosmatia-Idlocycloceras-Reinecketa* assemblage (late Lower and Middle Callovian): This assemblage is quite rich ; the eucyclocertin ammonoids are even better represented than in Kachchh. It mainly comprises *S. opis* (Sowerby), *S. discoidea* Spath, *I. perisphinctoides* Spath, *Reinecketa indosabauda* Parona and Bonarelli (including *R. tyrnniformis* Spath as its junior synonym), *Kinkelnicer* sp., *Indosphinctes* sp., *Grossouwia steinmanni* Parona and Bonarelli, G. sp., *Sivajicer* sp., and *Kutchisphinctes* sp. Definite Upper Callovian ammonoids are surprisingly unknown so far (earlier record of two Upper Callovian ammonoids by Singh and Jai Krishna (1969) were misidentifications), although the Callovian-Oxfordian succession appears to be continuous.

3. *Mayaites* assemblage (Upper Oxfordian) : It is represented by *Mayaites maya* (Sowerby), *Mayaites* spp., *Epimayaites* sp., *Dhosaites* sp., *Paryphoceras* sp., and *Pseudo-brightia* sp. In addition a good number of individuals of probably an unknown rather widely umbilicate mayaitin form are also present in this assemblage. Further studies on this ammonoid are in progress.

4. *Torquatisphinctes-Pachysphinctes-Lithacoceras* assemblage (Kimmeridgian?—Lower Tithonian) : This assemblage is meagre in comparison to coeval assemblage in Kachchh. It comprises *T.* sp. aff. *T. torquatus* (Sowerby), *T. alterneplicatus* (Waagen), *T.* spp., *Pachysphinctes bathyplocus* (Waagen), *P.* spp., *Lithacoceras albulus* (Oppel), *L. indicum* Collignon, *L.* spp., *Katrolliceras* ? sp., *Aulacosphinctes* sp. cf. *A. occultefurcatus* (Waagen), *Dichotomosphinctes* sp., *Virgatosphinctes communis* (Waagen), *Tarmelliceras* sp., *V.* sp. aff. *V. oppeli* Spath, *Anavirgatites* ? sp. etc. This assemblage is further divisible into 2 subassemblages (authors unpublished data) (a) *Torquatisphinctes* assemblage (oldest), (b) *Lithacoceras-Virgatosphinctes* assemblage.

After this assemblage the Jurassic part of the succession in Jaisalmer is devoid of ammonoids and the succeeding Mokal Member represents a gradually regressing sea.

6. *Deshayesites* assemblage (Lower Aptian) : It comprises *Lemuroceras* (or *Deshayesites*) *aburensis* Spath, *L. indicum* Spath, *Aconeceras* sp., *Pro-deshayesites bodei* von Koenen.

7. *Epicheloniceras* assemblage (Upper Aptian) : It is indicated only by a single specimen of *Epicheloniceras* sp. cf. *E. martini* (d'Orbigny).

8. *Douvilleiceras* assemblage (Lower and early Middle Albian) : It is modestly rich and comprises *Douvilleiceras mammilatus* (Schlotheim), *D. monile* (Sowerby), *D. inaequodum* Quenstedt, *Cleonicerias cleon* d'Orbigny, *C. baylei* Jacob, *Hamites subrotundus* Spath, *H. praegibbosus* Spath, *Hoplites ? dentatus* Sowerby, *Brancoceras* sp., *Lemuroceras* sp. and *Pseudosonnertia* ? sp.

(VI) Salt Range-Attock-Hazara—The Callovian-Albian sediments of these northern areas in the Pakistan part of the Indian subcontinent belong to the following stratigraphic units (Fatmi, 1972) :

3. Lumshival Formation		Aptian-Albian
2. Chichali Formation	} 2(3) Upper 2(2) Middle 2(1) Lower	Hautervian-Barremian
		Oxfordian-Valanginian
		Bajocian-Mid. Callovian
1. Samana Suk Limestone Formation		

Among these the upper part of 1, 2 (1) and 2(2) are ammonitiferous. In general the succession including that of ammonoid assemblages is better developed, more complete and also thicker in the Trans-Indus Salt Range. The ammonoids as elsewhere, are mostly found in nodules and the assemblages indicate condensation (Fatmi, 1972 and 1977). The Lr. and Mid. Callovian ammonoids are modestly developed in both *trans* and *cis* Indus Salt Range. Golden Oolite bands are present in the Callovian as in Kachchh, Baluchistan and Jaisalmer Upper Jurassic ammonoid assemblages are modest and developed only in *trans*-Indus Salt Range. The Berriasian and Valanginian are respectively indicated by *Subthurrmanita* and *Olcostephanus* on either side of the Indus. The Berriasian-Valanginian black marls and shales are not much different from that of Tethys Himalaya. The Aptian-Albian assemblages are developed only in Attock and Hazara. The assemblages may be summarised as follows (Spath, 1933, 1939 ; Fatmi, 1972, and 1977) :

1. *Macrocephalites* assemblage (early Lower Callovian) : It is indicated by *M. macrocephalus* Schlotheim, *M. subcompressus* Waagen, *M. lamellosus* Waagen, *Indocephalites* sp. aff. *I. transitorius* Spath, *Pleurocephalites habyensis* Spath, *A. harveyi* Sowerby and *Kamptokephalites* sp. cf. *K. magnumbicilatum* (Waagen).

2. *Subkossmatia-Indosphinctes-Reineckeia* assemblage (late Lower and Middle Callovian) : It comprises *Subkossmatia flemingi* Spath, *Reineckeia greppini* (Opell), *R. reissi* Steinmann, *Choffatia balinensis* Neumayr, *Indosphinctes* spp., *Grossouvria* spp.

3. *Mayaites* assemblage (Oxfordian) : It is indicated by *Mayaites maya* (Sowerby), *Epimayaites* sp. aff. *E. lemoine* Spath, *Peltoceratoides* sp., *Grayiceras* sp.

4. *Katroliceras-Pachysphinctes* assemblage (Kimmeridgian ?+Lr. Tithonina) : It comprises *Aspidoceras (Pseudowaagenia)* sp. indet., *Physodoceras* sp. indet., *Aspidoceras* sp., *Pachysphinctes robustus* Spath, *Katroliceras* sp. cf. *K. pottingeri* (Sowerby), *Hybonotoceras* sp., *Aulacosphinctoides* sp., *A. uhligi* Spath, *A. hazarensis* Fatmi, etc.

5. *Hildoglochiceras-Virgatosphinctes* assemblage (Md. Tithonian) : It is indicated by *Virgatosphinctes frequens* Spath, *V. densiplicatus* (Waagen), *Provalanginites rhodesi* Fatmi, *P. howarthi* Fatmi, *Proniceras indicum*, etc.

6. *Blanfordiceras-Himalayites* assemblage (Upp. Tithonian) : It consists of *B. walliichi* Gray, *B.* sp. cf. *B. latidomus* Uhlig, *Protacanthodiscus* sp. cf. *P. michaelis* Uhlig, *Himalayites* sp. cf. *H. depressus* Uhlig, *Boehmiceras middlemssi* Uhlig, *Himalayites* sp. cf. *H. hyphasis* Blanford, *Aulacosphinctes splitiensis* Uhlig.

7. *Subthurmania-Neocosmoceras* assemblage (Berriasian) : It is indicated by *Subthurmania fermori* Spath, *S. filosa* Spath, *S. transitoria* Spath, *Protacanthodiscus asiaticus* (Uhlig), *Spiticeras (Spiticeras) griesbachi* Uhlig, *S. (S.) mojsvari* Uhlig, *S. (Negrelicerias) tenuicostatum* Djanlidse, *Neolissoceras grasianum* (D'Orbigny), *Bochianites* sp. cf. *B. gerardianus*, *Berriasella* sp. indet., *Neocosmoceras octagonus* (Uhlig), *N. subradiatus* (Uhlig), etc.

8. *Douvilleicerias* assemblage (Lower and early Middle Albian) : It is indicated by *D. mammillatus* Schlotheim, *D. monile* (Sowerby) and *Brancoceras* sp.

9. *Oxytropidoceras-Dipoloceras* assemblage (late Middle Albian and Upper Albian) : It is represented by *Lyelliceras lyelli* (d'Orbigny), *L. cotteri* Spath, *D.* sp. aff. *D. bouchardianum* (d'Orbigny), *Hamites* sp. cf. *H. attenuatus* (Sowerby), *O. multifidum* (Steinmann) and *O. roissianum* (d'Orbigny).

(VII) **Baluchistan-Samana Range**—In eastern Baluchistan stray and disjunct ammonoids have been recorded from Callovian-Albian sediments spread along a north-south belt running almost from Karachi in the South to Waziristan and Quetta in the north for more than 500 miles, although the stratigraphy is poorly known and outcrops limited. The Callovian stage is distinctly indicated by a *Macrocephalites* assemblage at Mazar Drik with golden oolite bands. Tithonian is indicated by the record of *Virgatosphinctes densiplicatus* (Waagen), and *V.* sp. cf. *V. subquadratus* Uhlig collected by Nuttal (in Arkell, 1956) from the neighbourhood of Windar river at Bela in Baluchistan. The early Lower Cretaceous is developed as black belemniferous shales as in Salt Range, but any ammonoids from these shales are not yet known. The Aptian-Albian sediments in Baluchistan are also devoid of ammonoids. However, Albian ammonoids are known from Samana Range. The stratigraphic unit names used here are based on Shah (1978). The ammonoid succession is summarised as follows :

1. *Macrocephalites* assemblage (early Lower Callovian) : It is represented by *M. madagascariensis* Lemoine, *M.* sp. juv. aff. *M. formosus* (Sowerby), *Indocephalites dubius* Spath, *I.* sp. aff. *I. gibbosus* Spath, *Dolikephalites perlamellosus* Spath, *D. praetransiens* Spath, and *Pleurocephalites habyensis* Spath.

2. *Indosphinctes-Choffatia-Kinkelniceras* assemblage (late Lower and Middle ? Callovian) : It comprises *I.* sp. aff. *I. errans* Spath, *C. balinensis* (Neumayr), *C.* sp. aff. *C. recuperol* (Gemmellaro) and *K.* sp. aff. *K. subwaageni* Spath.

3. *Virgatosphinctes* assemblage (Tithonian) : It is indicated by the

presence of *V. densiplicatus* (Waagen) and *V. sp. cf. V. subquadratus* Uhlig.

4. *Douvilleiceras* assemblage (Lower and early Middle Albian) : It comprises *Douvilleiceras mammilatus* (Schlotheim), *Cleonicerias daveisi*, Spath, *Brancoceras indicum* Spath, *Hamites*, sp. cf. *H. attenuatus* Sowerby, *Pictetia* sp. cf. *P. astieriana* (d'Orbigny), and *Protanisoceras* sp. indet.

COMPARISON AND CORRELATION

As is amply evident from the correlation Table 1 the succession of ammonoid assemblages in the Tethys Himalayas (Spiti-Malla Johar, Nepal and S. Tibet) is more or less the same as in Kachchh, Baluchistan-Samana Range, Jaisalmer and Salt Range-Attock-Hazara, and the correlation is fairly good. However, many significant points of differences do project forth very clearly, mainly on account of differences in their environment and gaps in the ammonoid/stratigraphic successions. Assemblages are largely of shallow shelf, and hardly ever suggest depth conditions beyond the edge of continental shelf. Possible, but not necessary, indications of gradual deepening are reflected in the uppermost part of the Spiti Shale Formation by *Pterolytoceras exoticum* (Oppel), the trace fossil *Zoophycus* and gradually increasing radiolarian chert content. In general, nearshore shallower conditions, it appears, are preferred by belemnoids than ammonoids as exemplified by lower part of Spiti Shale Formation in the Tethys Himalaya, Lower Tithonian belemniferous grit with brachiopods and corals of Bhadasar Member in Jaisalmer, early Neocomian belemniferous marls in Salt Range and Baluchistan, etc. Stage by stage correlation of the ammonoid assemblages is built up as follows (Table 1) :

Callovian-Oxfordian—Early Lower Callovian index ammonoid *Macrocephalites* is present in the basal Callovian sediments in all the areas under consideration which provides a perfect correlation, however, this assemblage is meagre in the Tethys Himalaya, Salt Range and Baluchistan in contrast to beautiful development in Kachchh. Late Lower and Middle Callovian is once again depleted in terms of ammonoids in the Himalaya, Salt Range and Baluchistan, but good correlation is provided by the index genera *Subkossmatia*, *Reineckeia*, *Indosphinctes*, *Grodsouvia* and *Choffatia*. Upper Callovian ammonoids are missing in most of the areas including the Tethys Himalaya, except for Kachchh. The Oxfordian assemblages are better known in Nepal than Spiti-Malla Johar, but best developed in Kachchh. However, *Mayaites* and *Epimayaites* indicate a perfect correlation except in Baluchistan where this fauna is not known. Lithologically, Callovian sediments in all the areas and Oxfordian in Kachchh and Jaisalmer are dominantly oolitic with presence of golden oolitic bands in the early Callovian (not necessarily

TABLE 1

Callovian-Albian ammonoid stratigraphy in the Indian Subcontinent.

STAGE	TETHYS HIMALAYA			AREAS IN THE WEST AND NORTHWEST							
	SPITI-MALLA JOHAR	NEPAL	S TIBET	KACHCHH	BALUCHISTAN etc.	JAISALMER	SALT RANGE etc.				
ALBIAN	UPPER	With out ammonoids	With out ammonoids	Mrt-Dpl	GURU FORMATION	?	?	Oxyt Dpl			
	MIDDLE			BHUJ FN				Continental	Dlc	Dlc	Dlc
	LOWER			CHIKKIM FORMATION				UKRA FN	Trp-Chl-Ast	ABUR FN	Epch.
APTIAN	UPPER	With out ammonoids	CHUCK FN	?	GORU FORMATION	?	?	?			
	LOWER								Dsh-Chl-Trp	Dsh	
BARREMIAN	BARREMIAN	G.S. FN	CHUCK FN	Nhp.	SEMBAR FN	?	?	?			
	HAUTERVIAN								Continental	PARIHAR FN	Continental
NEOCOMIAN	VALANGINIAN	Ncs-Dst	Brr-Bhm	?	UMIA FORMATION	?	?	?			
	BERRIASIAN								Bln	Vrg-Hml-Bln	Hpl-Vrg
TITHONIAN	UPPER	Hml-Crn-Alct	Vrg-Hml-Bln	Hpl-Vrg	KATROL FN	Vrg.	?	Bln Hml			
	MIDDLE	Hld-Vrg	Alcd-Ktr	Hld-Vrg	UMIA FORMATION	?	?	Hld-Vrg			
	LOWER	Trq-Alcd	Alcd-Ktr	Trq-Ktr-Sbd	KATROL FN	Trq-Pch-Lth	?	Ktr-Pch			
KIMMERIDGIAN	UPPER	?	?	?	TAKATU FORMATION	?	?	?			
	LOWER	?	?	?	TAKATU FORMATION	?	?	?			
OXFORD	UPPER	Myt	Myt	?	CHILITAN FN	?	?	Myt			
	LOWER	?	Pitd	?	CHILITAN FN	?	?	Pitd			
CALLOVIAN	UPPER	?	?	?	CHILITAN FN	?	?	?			
	MIDDLE	Pnc Grs	Ind-Grs	?	CHILITAN FN	Ind-Chl-Knk	?	Sbk-Ind-Rnc			
	LOWER	Mcr	Mcr	Mcr	CHILITAN FN	Mcr	Mcr	Mcr			

Generic name abbreviations are as follows : *Mcr.*—*Macrocephalites*, *Rnc.*—*Reineckeia*, *Grs.*—*Grossouvia*, *Ind.*—*Indosphinctes*, *Sbk.*—*Subkosmatia*, *Idc.*—*Idiocycloceras*, *Chf.*—*Choffatia*, *Knk.*—*Kinkeliniceras*, *Plt.*—*Peltoceras*, *Pltd.*—*Peltaceratoides*, *Myt.*—*Mayaites*, *Trq.*—*Torquatisphinctes*, *Alcd.*—*Aulacosphinctoides*, *Ktr.*—*Katroliceras*, *Sbd.*—*Subdichotomoceras*, *Pch.*—*Pachysphinctes*, *Lth.*—*Lithaceras*, *Hld.*—*Hildoglochiceras*, *Vrg.*—*Virgatosphinctes*, *Hml.*—*Himalayites*, *Crn.*—*Corongoceras*, *Alct.*—*Aulacosphinctoides*, *Bln.*—*Blanfordiceras*, *Hpl.*—*Haploceras*, *Berr.*—*Micranthoceras*, *Umt.*—*Umities*, *Ncs.*—*Neocosmoceras*, *Distoloceras*, *Brr.*—*Berriasella*, *Bhm.*—*Boehmiceras*, *Sbt.*—*Subthurmancia*, *Nhp.*—*Dst.*—*Neohoploceras*, *Olcs.*—*Olcostephanus*, *Dsh.*—*Deshayesites*, *Chl.*—*Chelonicerias*, *Trp.*—*Tropaem*, *Ast.*—*Australiceras*, *Epch.*—*Epicheloniceras*, *Dlc.*—*Douvilleiceras*, *Mrt.*—*Mortoniceras*, *Dpl.*—*Dipoloceras*, and *Oxyt.*—*Oxytropidoceras*.

at the base) in Kachchh, Jaisalmer and Salt Range. Late Oxfordian Dhosa Oolite Member of Kachchh also stands out prominently at the top in several dome like outcrops. These provide sort of broad markers for Lower Callovian and Upper Oxfordian.

Kimmeridgian

The presence of definite Kimmeridgian ammonoids is somewhat controversial from areas of the Indian subcontinent. Fatmi (1972) considers strata with *Aspidoceras*, *Katrolliceras*, *Pachysphinctes*, etc. as underlying the strata with *Aulacosphinctoides*, *Hildoglochiceras*, etc. Kimmeridgian, while Spath (1933), Arkell (1956), Enay (1973) and many other workers prefer *Torquatisphinctes-Pachysphinctes-Katrolliceras* assemblage as belonging to basal Tithonian (standard HYBONOTUM Chronozone). The author considers definite Kimmeridgian ammonoids to be absent in the Indian subcontinent, however, the possibility of a few species of *Torquatisphinctes*, *Aspidoceras* and *Hybonoticeras* extending into Kimmeridgian cannot be ruled out. The presence of the Kimmeridgian sediments is indicated by the rich assemblage of dinoflagellates of definite Kimmeridgian age (Jain *et al.*, 1980) from the strata immediately underlying the lowest Tithonian sediments containing *Torquatisphinctes*, *Aulacosphinctoides*, etc. in Malla Johar area.

Tithonian

Lower Tithonian ammonoids are well developed in the Tethys Himalaya as well as Kachchh Jaisalmer and Salt Range. The correlation is very good in view of the presence of common index genera of the Lower Tithonian. The author believes that the two most characteristic genera in the Lower Tithonian *Torquatisphinctes* and *Aulacosphinctoides* are not much different from each other morphologically to permit separate generic status to them as granted by Spath (1923, 1925). It was moreover done by Spath more in view of their different ages (in his opinion only) than morphology (Spath, 1933). Field and dinoflagellate evidence in favour of a continuous sedimentation in Malla Johar make it more logical to consider *Aulacosphinctoides* to be of Lower Tithonian age i.e. same as that of similarly looking *Torquatisphinctes*. These two genera are, thus here, considered of Lower Tithonian age (may be coeval or *Torquatisphinctes* appearing slightly earlier than *Aulacosphinctoides*) as well as occurring together in the Tethys Himalaya and western India (Kachchh and Jaisalmer). Taxonomic revision of this fauna is currently in progress. The Middle Tithonian *Hildoglochiceras-Virgatosphinctes* assemblage is scanty and inseparable from the early Upper Tithonian assemblage except in Malla Johar and Kachchh. Upper Tithonian ammonoid fauna is very beautifully developed in the Tethys Himalaya in Spiti Malla Johar and Nepal. Jai Krishna *et al.* (in press) have identified two separate assemblages in succession

of each other in the Upper Tithonian of Malla Johar ; (a) early Upper Tithonian assemblage of himalayitins and (b) late Upper Tithonian *Blanfordiceras* assemblage. Coeval of early Upper Tithonian is only distinct in Kachchh but is skeleton like and rather signals the gradual withdrawal of ammonoids from the Kachchh scene, having already withdrawn earlier from Jaisalmer. Stray Upper Tithonian ammonoids are also moderately developed in Salt Range. Rare records of Tithonian virgatosphinctins are recorded from Baluchistan as well.

Berriasian-Valanginian

Neocosmoceras-Distoloceras assemblage of Malla Johar has its elements present in the undifferentiated late Upper Tithonian—Early Neocomian fauna in Nepal. Coeval fauna in Salt Range is dominated by *Neocosmoceras* and *Olcostephanus*, while in S. Tibet it is only known through *Neohoploceras*. Common ammonoid genera *Boehmiceras*, *Pterolytoceras*, *Bochianites*, *Berriassella*, *Spiticeras*, *Subthurmannia* indicate strong correlation for the Berriasian part and the index ammonoids *Olcostephanus*, *Distoloceras* and *Neohoploceras* for the Valanginian. The late Neocomian sediments are significantly devoid of ammonoids in all the areas either signalling withdrawal of the sea or shallowing of the depositional site. In Spiti-Malla Johar, Baluchistan, Salt Range and S. Tibet these sediments are marine (Giumal Sandstone Formation and its equivalents), while in Kachchh, Jaisalmer and Nepal these sediments are continental containing the Upper Gondwana *Ptilophyllum* flora. The correlation is based on either *Ptilophyllum* flora or indirectly on the underlying and overlying assemblages.

Aptian

The Aptian ammonoids are present only in Kachchh, Jaisalmer and Nepal and correlate well on the basis of index genera *Deshayesites*, *Chelonoceras* and *Tropaeum*.

Albian

Albian assemblages are well developed in Jaisalmer and Samana Range (Lower and early Albian), Attock-Hazara (entire Albian) and S. Tibet (late Middle and Upper Albian). Lower and early Middle Albian *Douvilleiceras* assemblage correlates well in the first 3 areas in view of the common occurrence of index ammonoids *Douvilleiceras*, *Cleonoceras*, *Branconoceras*, etc. while the late Middle and Upper Albian *Dipoloceras-Mortoniceras* assemblage correlation is based on the common occurrence of *Dipoloceras* and *Mortoniceras*.

AMMONOID FAUNAL SIMILARITY

Based on the distribution of ammonoid genera (Tables 2-4) and subgenera

TABLE 2
DISTRIBUTION OF AMMONOID GENERA

Distribution of ammonoid genera/subgenera in different areas of the Indian Sub-continent during different successive stage/ substage time intervals. The abbreviations K, B, J, SR, SM, N and ST in the Tables 2-4 and Figs. 1-3 respectively stand for Kachchh, Baluchistan, Jaisalmer, Salt Range, Spiti-Malla Johar, Nepal and S. Tibet.

Gen./Subgen.	Areas	K	B	J	SR	SM	N	ST
EARLY LR. CALLOVIAN								
<i>Macrocephalites</i>		1	1	1	1	1	1	1
<i>Indocephalites</i>		2	2	2	2		2	
<i>Pleurocephalites</i>		3	3		3			
<i>Kamptokephalites</i>		4		4	4	4		4
<i>Nothocephalites</i>		5		5				
<i>Dolikephalites</i>		6	6	6		6		
<i>Kheraiceras</i>		7	7					
<i>Epmorphoceras</i>		8		8				
LATE LR. & MID. CALLOVIAN								
Eucycloceratinae :								
<i>Eucycloceras</i>		1		1				
<i>Subkossmatia</i>		1		1	1			
<i>Idiocycloceras</i>		1		1				
Reineckeidae :								
<i>Reineckeites</i>		2		2		2		
<i>Reineckeia</i>		2	2	2	2			
Proplanulitinae :								
<i>Kinkelinceras</i>		3	3	3	3			
<i>Obtusicosites</i>		3		3	3			
<i>Hubertoceras</i>		3		3	3			
<i>Sivajiceras</i>		3		3				
<i>Cutchisphinctes</i>		3		3				
Pseudoperisphinctinae :								
<i>Choffatia</i>		4	4	4	4			
<i>Grossouvria</i>		4		4		4		
<i>Bnatisphinctes</i>		4					4	
<i>Indosphinctes</i>		4	4	4			4	
<i>Subgrossouvria</i>		4		4				

(Continued)

Gen./Subgen.	Areas	K	B	J	SR	SM	N	ST
Hecticoceratinae :								
<i>Hecticoceras</i>		5						
<i>Lunuloceras</i>		5					5	
<i>Sublunuloceras</i>		5						
<i>Putealicerias</i>		5						
<i>Kheraites</i>		5						
Distichoceratinae :								
<i>Chanasla</i>		6						
<i>Sindeites</i>		6		6				
<i>Subbonarella</i>		6						
<i>Distichoceras</i>		6				6		
OXFORDIAN								
Mayaitinae :								
<i>Mayaites</i>		1		1	1	1	1	
<i>Epimayaites</i>		1		1	1	1	1	
<i>Dhosaites</i>		1		1				
<i>Paryphoceras</i>		1		1				
<i>Grayiceras</i>		1				1	1	
<i>Prograyicers</i>		1				1	1	
Pachyceratinae :								
<i>Pachyceras</i>		2						
Perisphinctinae :								
<i>Alligaticeras</i>		3					3	
<i>Properisphinctes</i>		3		3				
<i>Prososphinctes</i>		3			3			
<i>Perisphinctes</i>		3			3			
<i>Kranaosphinctes</i>		3			3		3	
<i>Orthosphinctes</i>							3	
<i>Ariesphinctes</i>		3			3		3	
<i>Dichotomosphinctes</i>		3			3			
<i>Dichotomoceras</i>		3						
<i>Discosphinctes</i>		3						
Pseudoperisphinctinae :								
<i>Klematosphinctes</i>		4						
Peltoceratinae :								
<i>Peltoceratoides</i>		5			5		5	
<i>Peltomorphites</i>		5						
<i>Parawedekindia</i>		5						

Gen./Subgen.	Areas	K	B	J	SR	SM	N	ST
Aspidoceratinae :								
<i>Euaspidoceras</i>		6			6			
<i>Paraspidoceras</i>		6						
Oppelidae :								
<i>Campylites</i>		7						
<i>Trimarginites</i>		7						
<i>Pseudobrightia</i>		7		7				

Note—Numerals 1-8 (for early Callovian) and 1-6 (for late Lower & Mid. Callovian) are used to differentiate respectively the genera/subgenera and subfamilies.

TABLE 3
(Same as in Table 2)

Gen./Subgen.	Areas	K	B	J	SR	SM	N	ST
LR. TITHONIAN								
Aspidoceratinae								
<i>Aspidoceras</i>		1			1		1	
<i>Physdoceras</i>		1			1	1		
<i>Pseudowaagenia</i>		1			1		1	
Simoceratinae :								
<i>Hybonoticeras</i>		2			2			
Virgatosphinctinae :								
<i>Subdichotomoceras</i>		3				3		
<i>Pachysphinctes</i>		3		3	3			
<i>Metagravesia</i>		3						
<i>Katrolliceras</i>		3		3	3	3	3	
<i>Torquatisphinctes</i>		3		3		3		
<i>Aulacosphinctoides</i>		3		3	3	3	3	
<i>Subplanites</i>		3		3			3	
<i>Anavirgatites</i>				3?				
<i>Virgatosphinctes</i>		3	3	3	3	3	3	
Ataxioceratinae :								
<i>Lithacoceras</i>		4	4					
Tarmelliceratinae :								
<i>Metahaploceras</i>		5						

(Continued)

Gen./Subgen.	Areas	K	B	J	SR	SM	N	ST
<i>Tarmelliceras</i>		5		5				
<i>Hemihaploceras</i>		5						
Streblitinae :								
<i>Uhligites</i>						6	6	
<i>Gymnodiscoceras</i>					6	6		
Berriasellinae :								
<i>Aulacosphinctes</i>		7		7	7	7	7	
<i>Lemencia</i>							7	
MID. & UPP. TITHONIAN								
Virgatosphinctinae :								
<i>Aulacosphinctoides</i>		1			1	1	1	
<i>Virgatosphinctes</i>		1	1		1	1	1	
Himalayitinae :								
<i>Corongoceras</i>						2	2	
<i>Aulacosphinctes</i>		2			2	2	2	
<i>Himalayites</i>					2	2	2	
<i>Micracanthoceras</i>		2						
Berriasellinae :								
<i>Berriasella</i>						3	3	
<i>Substeueroceras</i>						3	3	
<i>Protacanthodiscus</i>					3			
<i>Raimondiceras</i>					3			
<i>Blanfordiceras</i>					3	3	3	
<i>Kossmatia</i>						3	3	
<i>Paraboliceras</i>						3	3	
<i>Paraboliceratoides</i>						3	3	
Spiticeratinae :								
<i>Proniceras</i>			4		4			
<i>Umiates</i>		4						
<i>Spiticereras</i>					4	4		
Haploceratidae :								
<i>Haploceras</i>		5				5		
<i>Hiploglochiceras</i>		5			5	5		
<i>Provalanginites</i>					6			

Note—Numerals 1-7 are used for differentiation of the subfamilies,

TABLE 4. (Same as in Table 2)

Gen. or Subgen.	Areas	SR	SM	N	Gen. or Subgen.	Areas	K	J	N
BERRIASIAN-VALINGINIAN					APTIAN				
Spiticeratinae :					Deshayesitidae :				
<i>^ egrelliceras</i>		1			<i>Deshayesites</i>		1	1	1
<i>Groebericeras</i>				1	<i>Prodeshayesites</i>			1	1
Olcostephaninae :					Chelonicerases				
<i>Olcostephanus</i>		2			<i>Chelonicerases</i>		2	2	
<i>Rogersites</i>		2			<i>Epicheloniceras</i>			2	
Berriassellinae :									
<i>Subthurmania</i>		3			<i>Tropaem</i>		3	3	
<i>Boehmiceras</i>		3	3	3	<i>Australiceras</i>		3		
Neocomitinae :					Aconeceratinae :				
<i>Thurmanniceras</i>		4	4	4	<i>Sanmartinoceras</i>				4
<i>Neocomites</i>		4	4		<i>Aconecerases</i>			4	4
<i>Odontodiscoceras</i>		4	4		Acanthoplitinae :				
<i>Calliptyhoceras</i>			4		<i>Colombiceras</i>			5	
<i>Parandiceras</i>		4			LR. & EARLY MID.				
<i>Kilianella</i>		4			ALBIAN				
<i>Neocosmoceras</i>		4			Douvilleiceratinae :				
<i>Sarasinella</i>		4	4		<i>Douvilleiceras</i>		1	1	1
<i>Neohoploceras</i>		4			Hoplitidae :				
<i>Distoloceras</i>		4	4		<i>Cleonicerases</i>		2	2	2
<i>Acanthodiscus</i>		4	4		<i>Lemurocerases</i>			2	
Lytoceratinae :					<i>Hoplites</i>				
<i>Pterolytoceras</i>		5	5	5	<i>Pseudosonnertia</i>			2	2
Bochianitinae :					Brancoceratinae :				
<i>Bochianites</i>		6	6		<i>Brancoceras</i>		3	3	3
Spath's unnamed gen.	1	7			Hamitidae :				
" " "	2	7			<i>Hamites</i>		4	4	4
" " "	3	7			<i>Metahamites</i>				4
					Anisoceratinae :				
					<i>Protanisoceras</i>				
					Lytoceratinae :				
					<i>Pictetia</i>				
					Puzosiinae :				
					<i>Puzosia</i>				
					Acanthoplitinae :				
					<i>Hypacanthoplites</i>				

Note—Numerals 1-7 are used for differentiation of the subfamilies.

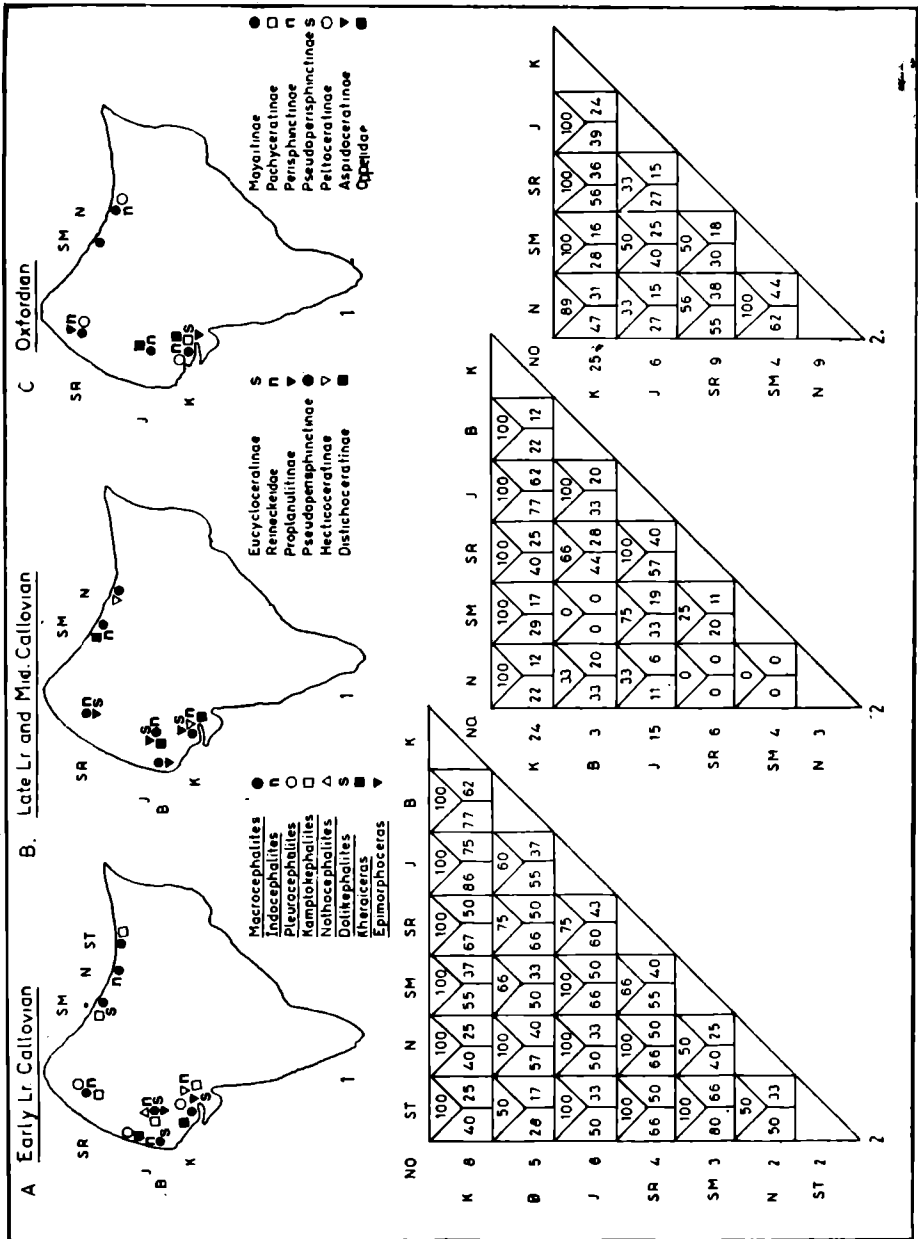


Fig. 1

Figs. 1-2. Distribution of ammonoid genera/families in different areas of the Indian Subcontinent along with the triangular diagrams indicating Faunal Similarity Coefficients (Simpson Coefficient at the top, Dice Coefficient at the bottom left and Jaccard Coefficient at the bottom right inside each small square) between different pairs of areas in the Indian Subcontinent.

in different areas of the Indian subcontinent for stage and substage time intervals Simpson, Dice and Jaccard Faunal Similarity Coefficients are calculated (Figs. 1-2). Ammonoid endemism based on subfamily and/or similar genera and subgenera is plotted on predrift geographic reconstruction of Pangea after Owen (1976). In general high similarity coefficients are indicated among the pairs Tethys Himalaya vs. Coastal areas in north and northwest. Kachchh/Jaisalmer/Baluchistan/Salt Range vs. Spiti-Malla Johar/Nepal values are always either high or moderately high for all the stage and substage time intervals. It is unfortunate that the present knowledge of ammonoid species from these areas is insufficient for such a detailed quantitative evaluation. The assemblages which are very meagre as of S. Tibet during the Jurassic and Neocomian are excluded from such a quantitative evaluation.

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High similarity coefficient values among different pairs of the areas in the Indian subcontinent show that the long held view (Uhlig, 1903-10; Spath, 1933, Enay, 1973) of their belonging to separate faunal provinces (Himalayan province and Ethiopian/Indo-Malgassy province) within the Tethyan realm, are untenable any more. In contrast all these shallow shelf areas of the Indian subcontinent belong to a single faunal province extending from E. African areas on the west through the above areas of the Indian subcontinent to Indonesia and New Guinea in the east, which is informally named here as Indo-E. African province (Fig. 3). It is characterised by the presence of endemic ammonoids (eucycloceratins in the late Lower and early Middle Callovian namely *Subkossmatia*, *Eucycloceras* and *Idiocycloseras*, mayaitins in the Upper Oxfordian namely *Mayaites*, *Epimayaites*, *Dhosaltes* and *Paryphoceras*, and virgatosphinctins in Lower Tithonian—namely *Katrolliceras*, etc.). It is significant to note that the endemic elements get substantially reduced in all the post Lower Tithonian ammonoid assemblages, which largely acquire later a pandemic or cosmopolitan character within the Tethyan realm. This point has also been impressed earlier by the author (1968, 1975b, 1979a and 1980) although in restricted context of Jaisalmer assemblages. The possible explanations relate to dismembering of Gondwana components and accompanying geodynamics in the Indian Ocean region, which are beyond the scope of this paper, and are proposed to be discussed later elsewhere.

CONCLUSION

The Callovian-Albian ammonoid stratigraphy and palaeobiogeography in the Indian subcontinent elaborated in this paper contributes significantly

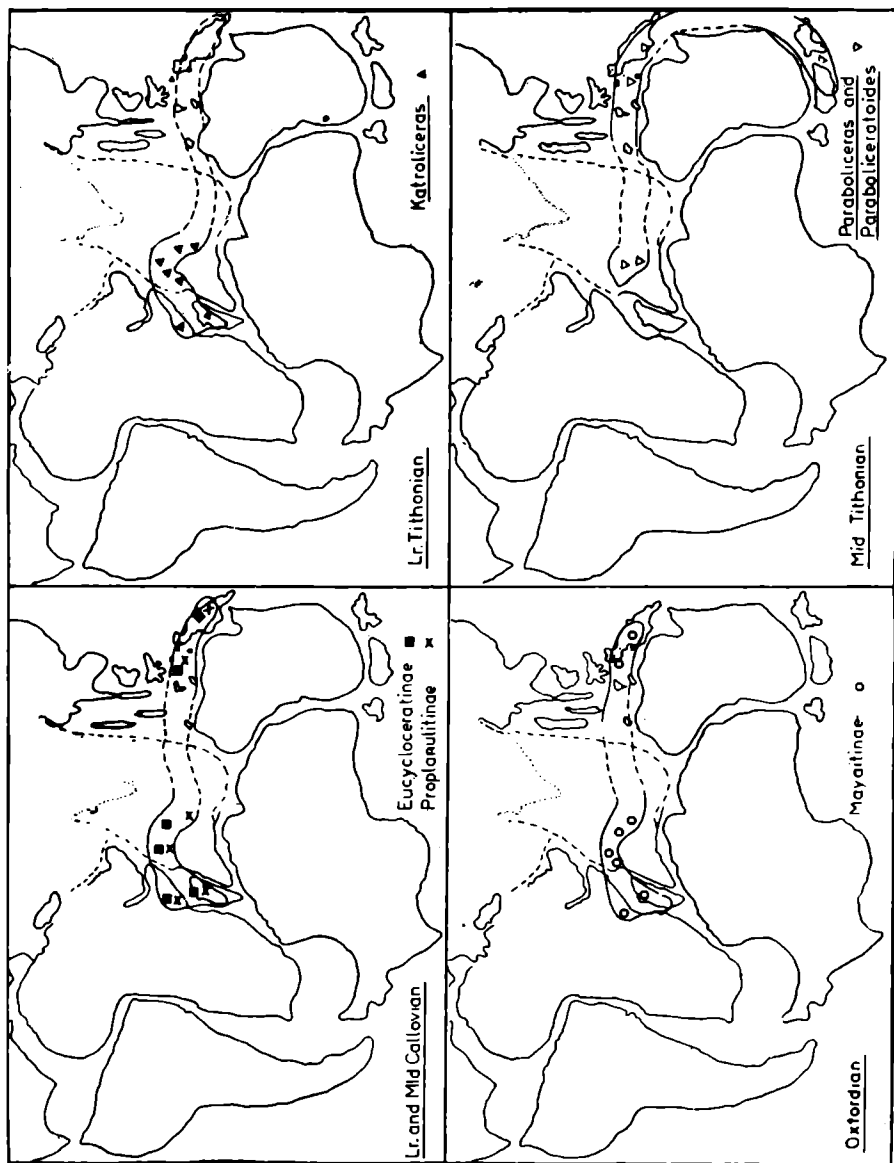


Fig. 3. Probable extent of the Indo-East African Ammonoid Faunal Province (within the Tethyan Realm) for successive stage and substage time intervals (Lower Callovian to Middle Tithonian).

many fronts ; first, it presents the first stage by stage build-up of ammonoid assemblages in all the principal regions of the Indian subcontinent (around the margins of the Indian plate), projecting forth, among them, a good correlation thus dislodging the long held myth that west and northwest Indian subcontinent successions are difficult to correlate with those of the Tethys Himalaya because of facies and/or age differences of the ammonoid faunas, the former ones being coastal and the latter being deep water geosynclinal. Secondly, this is the first Indian attempt towards quantitative evaluation of faunal similarities by the application of Simpson, Dice and Jaccard faunal similarity coefficients. Finally, the present exercise brings out very clearly that the Callovian-Albian shelf areas around the margin of the Indian plate belong to one single marine faunal province instead of separate Himalayan and Ethiopian faunal provinces as advocated by Uhlig, 1911 ; Spath, 1933 and Enay, 1973).

ACKNOWLEDGEMENT

The author is thankful to Dr. G.E.G. Westermann, McMaster University, Canada for many inspiring discussions while in Canada on a post-doctoral fellowship in 1979, besides free access to his collection of reprints.

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