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PERMIAN-TRIASSIC BOUNDARY OF INDIAN SUBCONTINENT AND ITS INTERCONTINENTAL CORRELATION

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Abstract

The Permian-Triassic boundary in the Himalayas is reviewed and discussed in the light of palaeontologic and stratigraphic data collected during the past two and a half decades from Kashmir, Spiti and Nepal. The deposition of the Kuling Shales and their equivalents in different parts of the Himalayas was followed by shallowing and regression of the sea. Sedimentation was interrupted at the top of Kuling Shale sequence resulting in the emergence of many areas. This was followed by widespread and simultaneous marine transgression resulting in deposition of *Otoceras*-bearing beds. *Otoceras woodwardi* Zone has been assigned to the Griesbachian age. The base of *Ophiceras tibeticum* Zone corresponds to the base of *Isarcicella isarcica* conodont zone; the disappearance of *Otoceras*, Permian brachiopods and other holdovers. It is suggested that the base of *Gyronites frequens* Zone is the most befitting for demarcating and documentation of the Permian-Triassic boundary as this stratigraphic level corresponds to the end of the lowest faunal diversification and coincides with the Griesbachian-Dienerian boundary. This boundary is also marked by striking changes in conodont fauna from *Anchignathodus* and *Isarcicella* to *Kashmirella* and *Neospathodus*.

Introduction

The nature of the Permian-Triassic boundary encompassing, in some sections, a continuous sedimentation cycle has been brought out by various workers from Southern China, Nepal (Dolpo and Thinikhola), India (Kashmir and Spiti), West Pakistan (Salt Range and Trans-Indus Range), Iran (Julfa region in north-west Iran and Abadeh region in Central Iran), U.S.S.R. (Armenia and Azerbaijan), Greenland (Stosch), Southern Alps and in some parts of North America. An understanding of the complete sequence of biological events occurring during the close of the Permian and Early Triassic is very much desired for a proper demarcation of the boundary between the Permian and Triassic Systems. This becomes essential more so since this interval has traditionally been considered to make significant biological changes. (Table 1).

The present review is based on the author's own observations in different parts of the Himalayas (Kashmir, Spiti, Ladakh, Kumaon, etc.) and a reinterpretation of data published by geoscientists from other geological organizations working in different Universities/Organizations, etc. in India and abroad during the last few years. (Figure 1).

Keywords: Himalayas, India, Permian-Triassic

Kashmir

The Permian-Triassic sequences of Kashmir (Guryul

Ravine section and 3 km north of Barus) have become world famous as these are supposed to be comprised of beds equivalent to the highest horizons of Permian and the lowermost horizons of Triassic. The stratigraphy and palaeontology of these sections has been worked out in detail by Nakazawa *et al.* (1970) and Nakazawa and Kapoor (1981). Two new sections spanning the whole of the Zewan Formation and parts of Khunamuh Formation have recently been described from Pahalgam area of Kashmir [22]. In contrast to the Guryul Ravine and Barus sections, the newly described sections at Pahalgam show no signs of any sharp sedimentary break and these sections are much thicker. (Figure 2).

The Zewan Formation at Guryul Ravine is divided into four members (A-D) with Permian faunas and the Khunamuh Formation with six members (E-J). Nakazawa *et al.* (1975) classified the uppermost part of the Zewan Formation into their faunal division IV which is 2.6 and 3.0 metres thick at Guryul Ravine and Barus respectively. This zone has yielded various brachiopods characteristic of the *Lamnimargus himalayensis* Zone and also include some reworked brachiopods of the unique forms, the bivalve *Claraia bioni* Nakazawa was believed by these workers to represent a primitive *Claraia* and *Glyptophiceras* was re-identified by Furnish *et al.* (1973) from Dieners' specimens of so-called *Xenaspis* of *carbonarius* (Waagen). Overlying beds in faunal division E 2, at the base of the Khunamuh Formation, contain species of *Claraia* and *Otoceras*, in association with a typical Permian brachiopod *Pustula*, which although allegedly derived, has no known match with older species. This horizon is overlain by the beds yielding ammonoid *Ophiceras*. If we relate these faunal divisions from Kashmir to the conodont zones, it would appear that fauna IV is basal Gangetian, and the *Ophiceras* beds are Ellesmerian. (Figure 3).

It may be pointed out that *Lamnimargus himalayensis* is found reliably only in Member B. Shells so-called, in Khunamuh Formation (Member E), are not *Lamnimargus* or *Marginifera* but belong to the genus *Transennatia* related to the Late Permian species of Vedian age. (Figure 4).

Sweet (1970) studied the conodont fauna from different stratigraphical horizons exposed in the Guryul Ravine section. According to him, the conodonts from the lowest 20.5 metres of the sampled sections represent the *Anchignathodus typicalis* fauna, which characterizes a zone that straddles the Permian-Triassic boundary in West Pakistan and elsewhere. Rocks above the *Anchignathodus typicalis* Zone at Guryul Ravine have been correlated by Sweet (1970) with the Lower Triassic conodont zones of *Neogondolella carinata, Neospathodus dieneri* and *Neospathodus cristagalli.*

Ladakh

The Gungri Formation (=Productus or Kuling Shales) is well developed in the Southern Zanskar Range of Ladakh. In the section exposed south of and on the track approaching the crest of the Phitsi La Pass, the Gungri Formation is represented by a 50 metres thick succession of predominantly black silty mudstone or muddy siltstone and fine sandstone yielding *Lamnimargus himalayensis* (Diener) and *Spiriferella rajah* (Salter). The younger calcareous units of the Gungri Formation have yielded rare ammonoids, apparently *Xenaspis*. The biostratigraphy of Triassic succession in this region has not been worked out in detail in view of difficult terrain where sections of Lower, Middle and Upper Triassic rocks are exposed.

Spiti

The *Otoceras* bed of Griesbachian age in the Spiti Valley overlies the subjacent Gungri Formation (=Productus or Kuling Shales) and the latter has yielded abundant brachiopod fauna in its lower and middle parts corresponding to the *Lamnimargus himalayensis* Zone. The Gungri Formation exposed around the village Guling (Kuling) in the Pin Valley section of Spiti is represented by about a 55 metres thick succession of green-grey to black silty shales, black needle shales and black calcareous siltstones. Similar succession is also exposed in the ravine WNW of Mud (Muth), near Gechang and Chhidang anticline. At all these localities, Gungri Formation is overlain by the beds yielding *Otoceras*. (Table 2).

The Gungri Formation near lingti in the Spiti Valley (opposite the Pin River confluence with the Spiti River)is represented by a 30 metres thick succession of black needle shales, dark grey silty shales with black concretions yielding fauna corresponding to *Lamnimargus himalayensis* Zone. The lower portion of this succession has yielded well preserved specimens of *Zoophycus*. The younger units of this formation have yielded representatives of *Cyclolobus* and *Xenaspis* at several stratigraphic levels. The uppermost part of the Gungri Formation in this section has yielded brachiopods of the family *comelicaniidae (Spitispirifer bisulcatus)*. This brachiopod implies a Vedian, or early Dorashamian-probably early Changsingian age for the top of the Gungri Formation. This is substantially younger than the immediately underlying shales with *Cyclobus*, dated as Djulfian [67] **(Table 3 and Figure 5).**

The *Otoceras* beds exposed in different parts of Spiti Valley have yielded characteristic platform type conodonts corresponding to *Neogondolella subcarinata Anchignathodus typicalis* C.R.Z. and *Anchignathodus parvus* I.Z **(Table 4).**

Kumaon

The Permian and Triassic succession exposed in the Niti Pass section of Painkhanda is identical to the sections discussed above for the Spiti region. As in the case of Spiti, the *Otoceras* bed in the Kumaon Himalaya lie above the Productus Shales (=Gungri Formation of Ladakh and Spiti) which have yielded rich assemblage of brachiopods of Djulfian and Dorashamian age. The conodonts recorded from the Niti Pass section are also similar to those found in the Lilang section of Spiti.

The occurrence of *Claraia griesbachi* and *C. painkhandiana* was recorded from the Shalshal cliff section of Kumaon Himalaya by Bittner (1899) from the collections made earlier by C.L. Griesbach and C. Diener. The *Otoceras woodwardi* layer in the Shalshal cliff section is 30 cm thick, and it is only in its topmost part that *Claraia* occurs in profusion. It may be emphasized that the *Claraia* in this section makes its appearance only at the level where *Otoceras* becomes extinct.

Nepal

Well developed sequences of Late Permian and Early Triassic rocks are exposed in west and central Nepal and the best exposures of these are met with in Dolpo, north-west Nepal, extending eastwards as far as Manag. In these areas, the beds corresponding to the lower and upper units of the Zewan Formation are developed, with comparable faunas, and are followed by beds and faunas that indicate Nepalese sequences to be better and more complete than those of Kashmir. **(Figure 6).**

The beds corresponding to the Vedian substage have been assigned three successive stratigraphic units i.e. Nisal, Nambdo and Luri Members corresponding to the faunas of *Marginalosia Kalikotei* Zone. The overlying Kuwa Member of the Senja Formation has been assigned to Ogbinan substage and is characterized by faunas of *Atomodesma variable* Zone. It may be pointed out that the horizon corresponding to brachiopods of the Comelicaniidae family *(Spitispirifer bisulcatus)* yielding beds of Spiti has not, so far, been found in Nepal. This could possibly be due to its having not been found till late, or to the prevalence of different facies, and /or could equally well be because this zone is missing from Nepal. Thus there might be a time break represented by a disconfirmity between the late Djulfian Pija Shale Member and the overlying Nisal Sandstone Member.

The various members of the Senja Formation are overlain disconformably by the Pangjang Formation which is named after Pangjang Khola where type section of the formation is exposed. In north Dolpo, the Pangjang Formation is separated from the Nisal Sandstone Member by three members which are not developed in the Kali Gandakki area. In the Kali Gandakki area, the Pangjang Formation immediately overlies the Nisal Sandstone Member, as a unit which is about 1 meter thick. The detailed stratigraphic succession of the Pangjang Formation, east of Thini Ridge, north of Thinikhola is shown in Figs 7-9 [64]. The four carbonate units overlying uppermost of the Thinichu Group in the Dolpo region constitute part of the Pangjang formation of Waterhouse (1978). The oldest of these four carbonate units is represented by a 2 to 3 meters thick succession of dense red and purple carbonate (dolomite and calcareous rocks) in 2 to 4 cm bands yielding brachiopods and ammonoids (including *Otoceras concavum* of basal Griesbachian or Gangetian age).

The lower part of the Pangjang Formation has yielded brachiopods (including several Permian genera) such as *Spiriferella* and *Neospirifer*, with possible *Transennatia, Lino productus* and other productina. In addition, the presence of solitary corals, crinoids, stenoporid bryozoans has also been recorded in this section. The fauna is of undoubted Permian age and may correspond to the lower Pangjang Formation of Dolpo where Permian type brachiopods accompany rare *Otoceras concavum* [64]. Moreover, occurrence of *Otoceras* cf. *woodwardi* Griesbach has also been recorded from the Thinichu area, just above the layer yielding bryozoans [2]. The higher part of the succession is rich in ammonoids (including *Ophiceras*) which are embedded in carbonate.

The so-called Lower Triassic rocks of Nepal average about 25 meters in thickness and this succession consists of shales and nodular carbonates which constitute part of Pangjang and Thinigaon Formations. In addition to other fossils, this sequence has yielded Early Triassic conodonts (including *Anchignathodus typicalis, Neogondolella carinata, N.millesi, N. jubata,* etc) indicating more outershelf to basinal conditions of deposition.

Cyclolobus and Late Permian stratigraphy of the Himalaya:

The succession of Cyclolobids and other ammonoids from the Djulfian, Dorashamian and Dienerian of boreal regions is comparatively better preserved and complete in contrast to the succession exposed in different parts of the Tethyan region. The *Cyclolobus* bearing beds have been recorded from different parts of Himalaya and these have been considered to range in age from Djulfian to early and middle Dorashamian. In the Spiti Valley, occurrence of *Cyclolobus* has been reported from the Gungri Formation (=Productus/Kuling Shales) from beds lying 0.45 m; 1.3 m, 3.0 m and 9.0 m below the *Otoceras* bed which are well exposed in the Spiti river section exposed 1.5 km downstream from the confluence of Spiti river with the Lingti nala of Spiti Valley [5,27,67]. The beds yielding *Cyclolobus* at this locality are overlain by the strata containing brachiopods belonging to the family Comelicaniidae *(Spitispirifer bisulcatus)*. The beds yielding these brachiopods constitute the upper part of the Gungri Formation and are suggestive of a Vedian or early Dorashamian, perhaps early Changsingian, age for the top of the Gungri Formation. The possibilities for the existence of a hiatus covering a major part of Dorashamian (=Changsingian) in some sections of the Himalayas cannot be ruled out. It may be pointed out that the upper contact of the Gungri Formation with the overlying *Otoceras* bed in the Pin valley section of Spiti is represented by a 10 to 12 cm thick laterite/limonite pebbly layer, suggestive of a hiatus, probably a break in sedimentation and subaerial weathering [5]. This hiatus may involve part of the Djulfian Stage, and much or complete Changsingian or Dorashamian Stage of latest Permian age.

Since *Cyclolobus* from Spiti cannot be dated precisely in view of its possibly lengthy time range over two of more biozones, it is not possible to precisely indicate the length of time unrepresented in the Spiti column.

The analysis of various fossil records from the Gungri Formation of Spiti and parts of Ladakh indicates the existence of faunas at the base which are identical to those found in the lower part of the Zewan Formation. This is followed by the beds yielding *Cyclolobus* similar to those found in the upper part of the Zewan Formation. A very significant occurrence of Comelicaniidae from the upper part of the Zewan Formation has enabled us to tie the succession into the lower Bellerophonkalk of southern Europe and Iran (Lower Dorashamian). In contrast to Spiti Section, the Kashmir sequence of Guryul Ravine is comparatively more complete, with the Upper Zewan Formation (Member D) containing modestly diverse faunas of early Djulfian age, and the basal Khunamuh Formation (Member E-I) containing a very poor Vedian fauna of Dorashamian-Changsingian age.

The occurrence of *Cyclolobus walkeri* Diener has been recorded from the upper units of the Zewan Formation (upper part of Member C) of early Djulfian age [18,44,67] and the Ganiaroh Member of the Salt Range. In view of the proximity of the occurrence of *Cyclolobus* in parts of the Salt Range, Kashmir, Ladakh and Spiti during Permian time, it seems likely that the *Cyclolobus* in the Gungri Formation may possibly be of Djulfian age although it may be difficult to decide between a Punjabian or Djulfian age on the basis of associated brachiopod fauna. The specimen of *Cyclolobus* from the Gungri Formation are generally identified with *Cyclolobus walkeri* Diener, originally described from Chitichun No. I fauna, of Punjabian age and definitely not Djulfian to judge from its associated brachiopods.

In addition to *Cyclolobus walkeri* Diener, the upper Zewan Formation (Members C to D) has yielded ammonoid *Xenaspis*. This ammonoid ranges from Kalabagh to Chhidru in the Salt Range section of Pakistan. *Cyclolobus walkeri* in the Salt Range section has been reported from the Upper Chhidru Formation (=Djulfian) [43-44].

A fuller sequence of upper Permian succession is found in north-west Nepal, where the Nangung Formation with lower Zewan fauna is overlain by the Senja Formation with a sequence of members and faunal zones and comparatively rich faunas, although lacking the extremely localized and endemic ammonoids of China. The Senja Formation is of undoubted Dorashamian-Changsingian age.

Relationship of *Otoceras* Zone with the *Pseudotirolites* or *Paratirolites:*

The occurrence of *Otoceras* has been reported from nine regions along Circumarctic and Gondwana margin of the Indian plate. The distribution of this ammonoid shows typical bipolarity. Some workers have expressed opinions regarding the superposition of *Otoceras* Zone up to *Pseudotirolites* or *Paratrirolites* Zone on the palaeogeographic distribution of these forms. A majority of the workers consider *Otoceras* Zone to be of basal Triassic age. Since *Pseudotirolites* and *Paratirolites* Zones are considered to be of undoubted uppermost Permian, it is logical to assume that *Otoceras* may be superjacent to *Pseudotirolites* or *Paratirolites.* However, during the past decade biostratigraphers have been looking for a section which may provide the postulated ammonoid zonation but they have not been able to locate/find such a section.

In contrast to typical bipolarity shown by *Otoceras*, both *Pseudotirolites* and *Paratirolites* show tropical distributions. They are exclusively discovered either along the Eurasian margin or from intermediate tropical microcontinents of Tethys. Evidently, the *Otoceras* Zone is not bound to be superjacent upon *Pseudotirolites* or *Paratirolites* Zone, since they are biogeographically and phylogenetically separate. The only known exception is in Changxing, Zhejiang Province of South China, where fragments of *Otoceras* sp. have been recorded from beds overlying the horizon corresponding to the Permian *Pseudotirolites* Zone. *Otoceras* have also been reported from Susong in Anhui Province. Both these reports need further confirmation on the basis of additional field data and the collection of better preserved material. However, if the reported occurrence of these is finally confirmed and justified, these occurrences may be explained due to southward temperate paleocurrent carrying *Otoceras* shells along the northern margin of the Yangtze Platform [70,26].

Relationship of *Otoceras* bed with the *Concavum* Zone:

It is generally accepted on the basis of available field evidences that the *Otoceras* beds and the *Concavum* Zone may be of Permian age. However, some workers have suggested a downward extension of the *Otoceras* Zone into the Permian in the light of its correlation with ammonoids. Waterhouse (1978) has recorded the find of few upper Permian brachiopods from the lower part o *Otoceras* beds or *Otoceras concavum* Zone of Nepal Sweet (1979), applying graphic correlation of Permo Triassic rocks in Kashmir, Salt Range and Iran ha concluded that the lower part of the *Otoceras woodwara* Zone in western Himalaya overlaps with the *Paratirolite* Zone of Iran. Bando (1980) on the basis of close affinit between **Julfotoceras** from North Iran and *O concavum* from Canada has supported Waterhouse (1978 in that *Otoceras concavum* Zone underlies *Otocera woodwardi* Zone. *Julfotoceras* is a primitive otoceratic discovered in *Paratirolites* Zone. *Otoceras* beds of Spit valley (Lilang Section) have yielded platform type conodonts (including *Neogondolella subcarinata*) of Late Permian age.

It seems reasonable to assume that the *Otoceras* beds are bipartite. The lower part, i.e. *Otoceras concavum* bed contains only Permian time brachiopods, conodonts and other fossils. These beds have, so far, shown no evidence of its superposition on *Pseudotirolites* or *Paratirolites* Zones. The upper part, i.e. *Otoceras woodwardi* Zone corresponds to the *Anchignathodus parvus* I.Z. and the age of this horizon needs to be defined precisely.

Occurrences of *Otoceras* in Himalaya:

Otoceras woodwardi is found widely in the Himalayas of Kashmir (including Khunamuh Formation, level E-2 in Guryul Ravine, level f_2 at spur 3 km north of Barus and Pahalgam), Spiti and Central Himalayas. The Guryul Ravine section of Kashmir is perhaps an exception as it is supposed that it comprises the beds equivalent of the highest horizons of Permian. However neither the uppermost beds (Member D) of the Zewan Formation nor beds of the Member E-I of the Khunamuh Formation have yielded fossils suitable for correlation with Dorashamian of Changxingian. In addition, bed corresponding to *Otoceras concavum* have not so fa been found in the Guryul Ravine section of Kashmir The Guryul Ravine and Barus sections show a reworked storm-deposited sandy limestone at the top of the Zewa Formation, which may represent a significant time ga [66,22]. It may be pointed out that the Khumamu Formation (EI) has been shown by Nakazawa an Kapoor (1981) to start with a pre-*Otoceras woodwarc* fauna, and therefore, is likely to be pre-Griesbachian, c more accurately Gangetian for Griesbachian as defined the same essentially as the Himalayan term "Gangetic" proposed by Waagen (1891) and Diener (1895), for *Otoceras* and *Ophiceras* beds of Spiti and corresponding beds exposed elsewhere in the Himalayas.

The *Otoceras* bed exposed in different parts of the Spiti Valley (Lingtinala, Lilang, Mud, Guling, etc.) lie above the Gungri Formation and the contact between the two is represented by ochre-weathering grey, massive limestone and a 10 to 12 mm thick laterite/limonite pebbly layer suggesting the presence of a time gap/hiatus, probably a break in sedimentation and subaerial weathering. The recent work has proved that the *Otoceras* bed in Spiti is slightly more thick than so far considered and in some sections this may even exceed 50 cms.

The *Otoceras* bed similar to that of Spiti Valley is also exposed in the Shalshal cliff section of Kumaon Himalaya.

The base of Pagjang Formation in north-west Nepal has yielded *Otoceras* [68,64]. The presence of *Otoceras* cf. *woodwardi* has also been recorded from limestone in the Kali Gandaki Valley of Central Nepal [2]. The *Otoceras* bearing beds of Nepal support world-wide marine transgression during this time.

Age of *Otoceras* bed of Himalaya:

The opinions regarding the age of the *Otoceras* bearing beds differ considerably. At the turn of the century the *Otoceras*-bearing beds and *Otoceras woodwardi* Zone were never equated. The *Otoceras*-bearing beds were placed entirely or at least to some extent in the Upper Permian. The *Otoceras woodwardi* was included by some into the Triassic [40], and by others into the Upper Permian [50]. During the last few years some workers have placed the *Otoceras* bearing beds as well as the *Otoceras (Julfotoceras) concavum* and *Otoceras woodwardi* Zones into the Upper Permian [1,47,48,62-65,31,33,25,69]. Other workers continue to place the *Otoceras concavum* and *Otoceras woodwardi* Zones (and some authors even all *Otoceras* bearing beds) into the Triassic [46,58,71]. However, in those sections where *Otoceras* is not found, the time equivalent of these beds has generally been considered equivalent of the beds corresponding to the *Otoceras woodwardi* Zone. This is evident from the fact that the topmost zone of the Changxingian [71] with *Pseudogastroceras* (the last *Goniatite* genus), several forms of Permian brachiopods and other Permian elements was classified by all the workers as part of the topmost Upper Permian until Zhao *et al.* (1981) reported the find of *Otoceras* from these beds.

In the Himalayas, the stratigraphic implications of *Otoceras woodwardi* since its first find from the Shalshal cliff section of Kumaon Himalaya in 1879 has been the subject of controversy [19]. Griesbach (1891) considered the beds yielding this ammonite as "passage beds" between the Permian and Triassic Systems and as a horizon still lower than the Werfen of the Alps. Waagen (1891) correlated the *Otoceras* beds of Himalaya with the Djulfian ammonoid beds of the Transcaucasian U.S.S.R. which is indisputably placed in Upper Permian. The younger Permian age to the *Otoceras* bed of Himalaya was also assigned by Noetling (1900). However, Mojsisovics (1892) assigned Triassic age to the *Otoceras woodwardi* from the Himalaya in view of its being more evolved than the *Otoceras* found in the Djulfian section (Upper Permian). Diener (1909) considered Himalayan sequences to be very significant but his argument hinged entirely on "the complete absence of the numerous types of Palaeozoic brachiopods" from faunas that contained the ammonoids *Otoceras* and *Ophiceras*. This is now known to be false as there are several reports available recording the occurrence of Permian brachiopods from the beds yielding *Otoceras*. Permian productid are found with *Otoceras* and *Ophiceras* in Kashmir [46], and in north-west Nepal with *Otoceras*, and widely throughout the world as reviewed by Waterhouse (1972, 1973). Diener (1909) erred and that error has been enshrined, perhaps irrevocably, in literature. But faunally the *Otoceras* beds are Permian.

Diener (1909, 1912) demarcated the boundary between the Permian and Triassic Systems at the base of the beds yielding *Otoceras* in spite of his having admitted that the genus *Otoceras* is known outside Himalaya from Permian rocks.

Otoceras is accompanied in various parts of the world by faunas of Permian aspect, including microfauna, rugose corals, productids and other brachiopods, goniatites and various other life forms [31,62,63,69]. The conodonts from the *Otoceras* beds are essentially of Permian age. In spite of evidences to the contrary, the proponents of the historical view (i.e. Diener's view) continue to misrepresent the actual faunal succession, which all over the world was dominated by Late Palaeozoic life forms during the range of the Permian-

		Chinese-Japanese Research Group, 1984	Traditional Definition	Kozur H. 1978, 1980 Gupta and Kozur, 1983	Newell N.D. 1978	Waterhouse J.B. 1976	Budurov K. et al., 1986 Gupta V. J. (Present work)
Triassic	Dienerian			Triassic	Triassic *Gyronites Z.*	Dienerian ?	Dienerian
Triassic	Griesbachian	*Otoceras woodwardi Z.*	*Otoceras woodwardi Z.*	*Ophiceras commune Z.* / *Otoceras woodwardi Z.*	*Ophiceras Z.* Permian	Griesbachian	Griesbachian
Permian	Changhsingian	*Rotodiscoceras Z.* or *Palaeofusulina sinensis Z.*		Permian			

Table 1- Comparative table of the Permian-Triassic boundary scheme (based on Sheng *et al.* 1984).

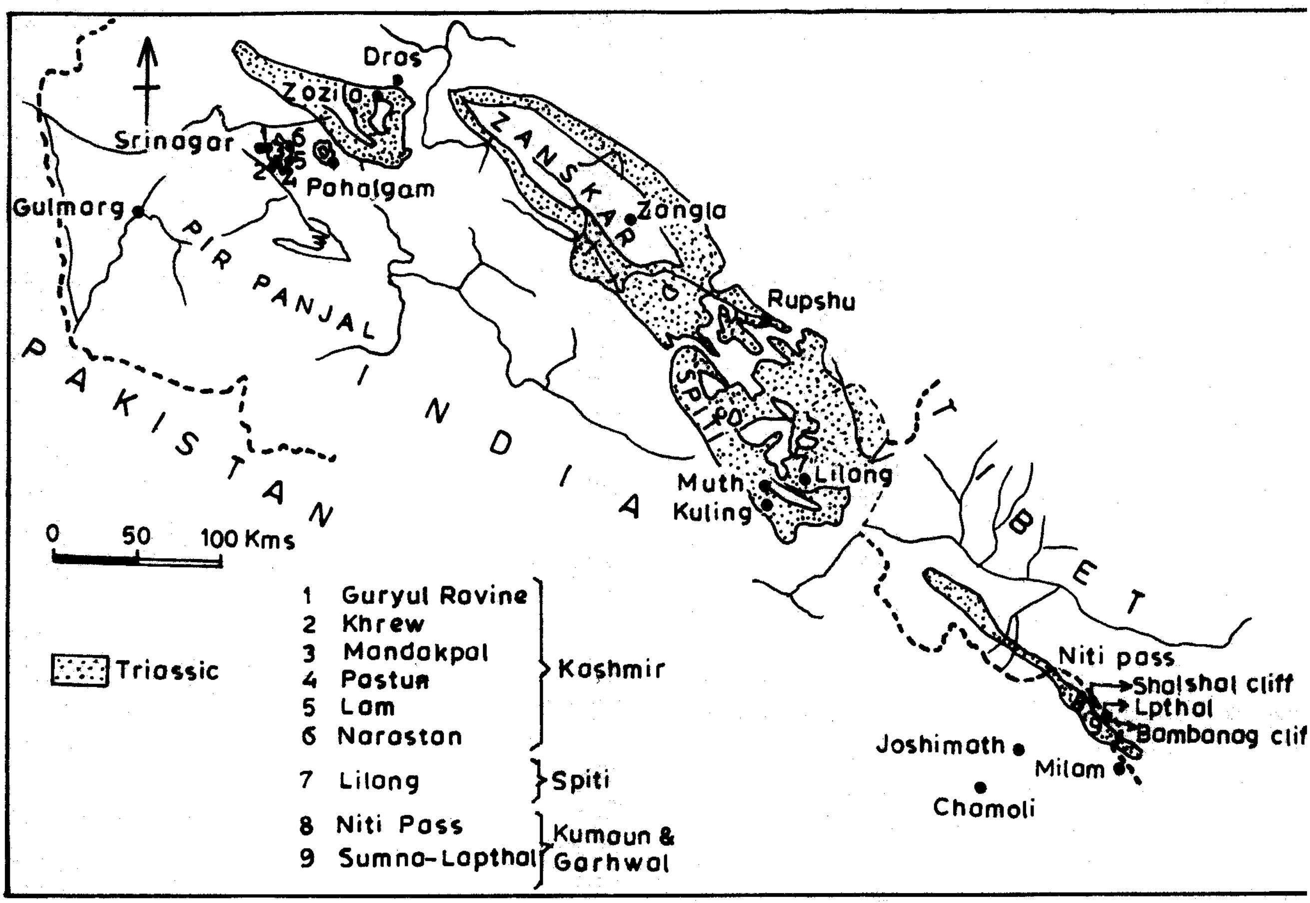

Figure 1- Sketch map showing distribution of Upper Permian and Triassic rocks in parts of Kashmir, Ladakh, Spiti and Kumaun Himalaya.

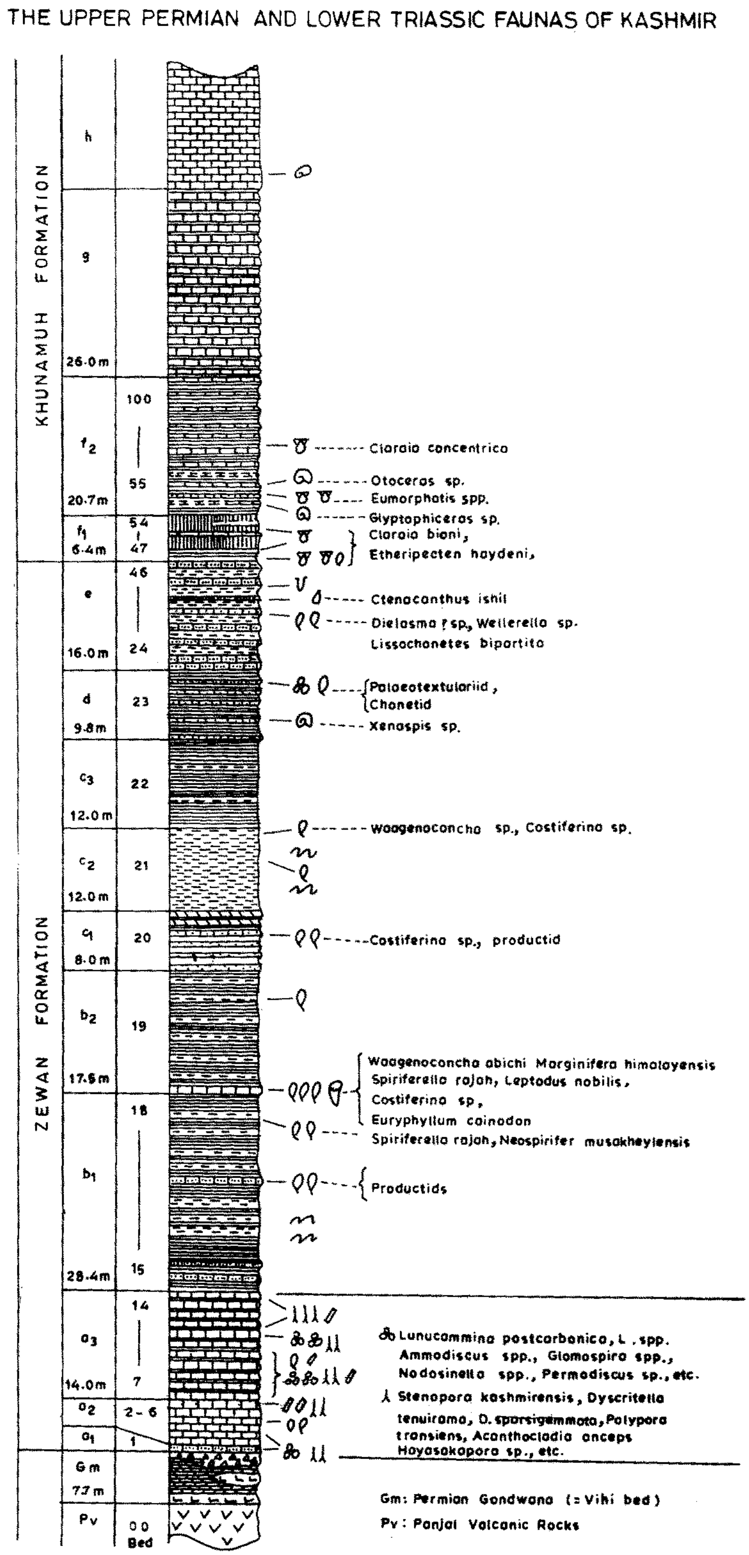

Figure 2- Columnar section and fossil occurrences at the spur 3 km north of Barus (after Nakazawa and Kapoor, 1981).

type ammonoid *Otoceras* [69]. *Otoceras* itself is a member of a family uniquely Permian amongst ammonoids. Kozur (1974) on the basis of conodonts and other studies; Newell (1973) on the basis of bivalvia and Waterhouse (1972, 1976) on the basis of brachiopods have argued that the *Otoceras* beds at least are essentially of Permian age.

According to some palaeontologists during the last few years the *Otoceras* bed may include part of the Dorashamian stage [47,32,33,61,64,68,25]. Comparision of faunas from west (and Central) Nepal and Kashmir shows that there exists substantial time breaks in the Permian of Kashmir. The Dorashamian Stage is virtually widespread, for the vestige of faunas in Khunamuh Formation (E-I) which may be of Late Vedian, and, of course, depending where it is placed as the *Otoceras-Ophiceras* beds have been regarded by some authors as of Late Dorashamian age. Only by including the latter with the Permian Period can Guryul Ravine sequences in Kashmir be regarded as offering satisfactory evidence on the Permian-Triassic boundary.

MIXED FAUNAS AND PERMIAN TRIASSIC BOUNDARY:

The Permian faunal elements were found by s workers in the *Otoceras woodwardi* Zone and, acc to some of them, these faunal elements co reworked. As a result, several papers on the occurr Permian-Triassic "mixed faunas" from the (*woodwardi* Zone were published. The Triassic am genus *Otoceras* and bivalves were found to be ass with Permian brachiopods, conodonts, foraminif But *Otoceras* is by no means a Triassic am genus. On the contrary, it is the last representat typical Upper Permian superfamily. The bivalves (*Claraia, Eumorphotis venetiana, Leptoc minima, Promyalina* sp.) are either known fron deeper section of the undisputed uppermost Perm (*Claraia*), or the immediate forerunners of these are quite unknown in the underlying un uppermost Permian due to facial variations. occurrence of these faunas in the *Otoceras* w

INTERNATIONAL		WEST NEPAL			KASHMIR	SPITI / LADAK
Stage	Substage	Formation	Member	Zone	Formation	Formati
Dorshamian	Ogbinan	Senja	Kuwa	*Atomodesma variable*	—	—
	Vedian		Luri Namdo Nisal	*Marginalosia kalikotei*	?Khunamuh EI	*Spitispirife (Comelica*
Djulfian	Baisalian		Pija	*Krotovia arcuata*	—	—
	Urushtenian		Popa	*Pyramus silicius*	Zewan D upper C	*Cyclolobu* Kungri
Punjabian (Midian)	"Chhidruan" — Kufrian	Nangung		*Lamnimargus himalayensis*	Zewan C lower B A	*L. himalc*
	Kalabaghian					

Table 2- Correlation of Himalayan Middle and Late Permian units (below the *Otoceras* Zone)

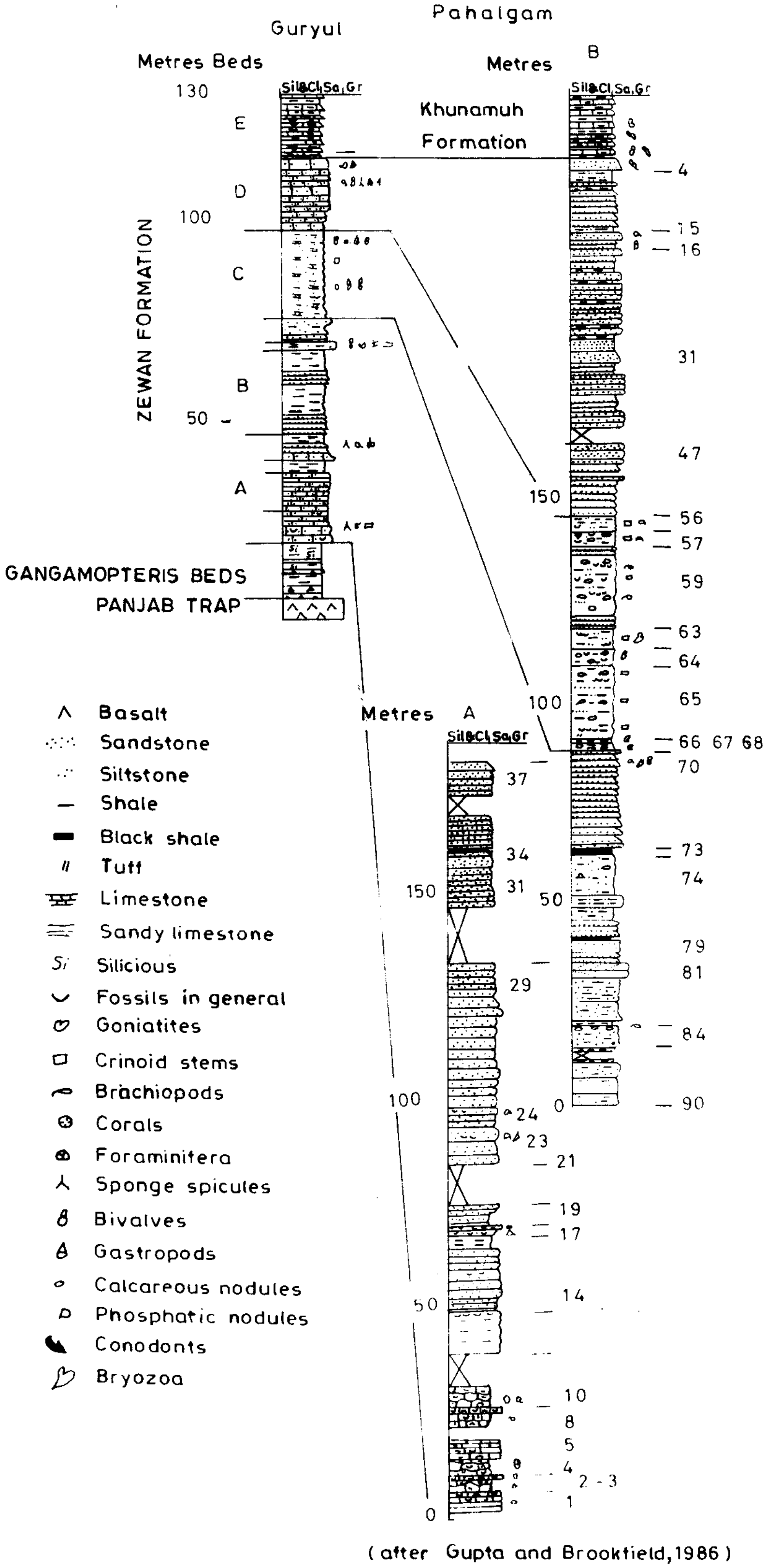

Figure 3- Sections A and B at Pahalgam with location of beds and fossils and tentative correlation of beds 34 in A with 73 in B. Divisions compared with Guryul Ravine Section at left (after Gupta and Brookfield, 1986).

Zone is most probably a facies controlled event. Certainly, it is difficult to say so about "Triassic" bivalves, if the immediate forerunners of these are unknown from the underlying undisputed topmost Permian beds due to facial changes. Biostratigraphy has to be based on phylomorphogenetic lines and not on the facies-controlled occurrence of some species. So, in fact the *Otoceras woodwardi* Zone has in its lower part a Permian fauna without the presence of Triasic elements. The first Triassic elements (e.g. *Anchignathodus parvus)* appears in the younger horizons. *Anchignathodus* is frequently found in the Upper Carboniferous and Permian and is a very conservative genus. Some new species and even genera evolved from the long ran *Anchignathodus minutus* and these conodonts disa near the top of the *Ophiceras commune* Zone. Triassic faunal elements were reported from the *Oto (Julfotoceras) concavum* Zone. Even the Triassic bi (with the exception of *Claraia*) are unknown from zone that has yielded quite typical Upper Per Conodonts and brachiopods faunas.

Teichert *et al.* (1970) interpreted the occurren mixed faunas in the Guryul Ravine section of Kas as the true association of surving "Permian" brachio with the typical Lower Triassic pelecypod *Claraia.*

According to Newell (1978), the principal event

PERMIAN PERIOD		SALT RANGE		WEST NEPAL		CHINA	
Stage	Substage	Formation	Member	Formation	Member	Formation	Zones
Dorashamian	Gangetian			Panjang		Changhsing	*Ophiceras* *Otoceras*
	Ogbinan			Senja	Kuwa		*Rotodiscoceras*
	Vedian				Luri		*Pseudotirolites*
					Nambo		*Tapashanites e*
				(?gap)	Nisal		gap —?
Djulfian	Baisalian	Chhidru	Khisor		Pija	Wuchiaping	*Sanyangites*
	Urushtenian —Abadehan		Ganjorah		Popa		*Araxoceras et*
							Anderssonoceras
Punjabian	Kufrian		Kufri	Nangung		Maokou	(gap —)
	Kalabaghian	Wargal	Kalabagh				*Yabeina*
Kazanian	Sosnovian		Virgal				*Neoschwagerin*
Kungurian			Katta				

Table 3- Correlation of younger Permian units in the Salt Range, Nepal and China. The Vedian of Armenia, with comelicaniid and *Phisonites* may be absent from South China and possibly from Nepal, so that the Nisal to Luri interval in Nepal and the *Tapashanites* to *Rotodiscoceras* Zones in China match the Ogbinan of Armenia, this is not shown in the present table. Wargal and Maokou down into lower Kazanian and Kungurian (Modified after 6).

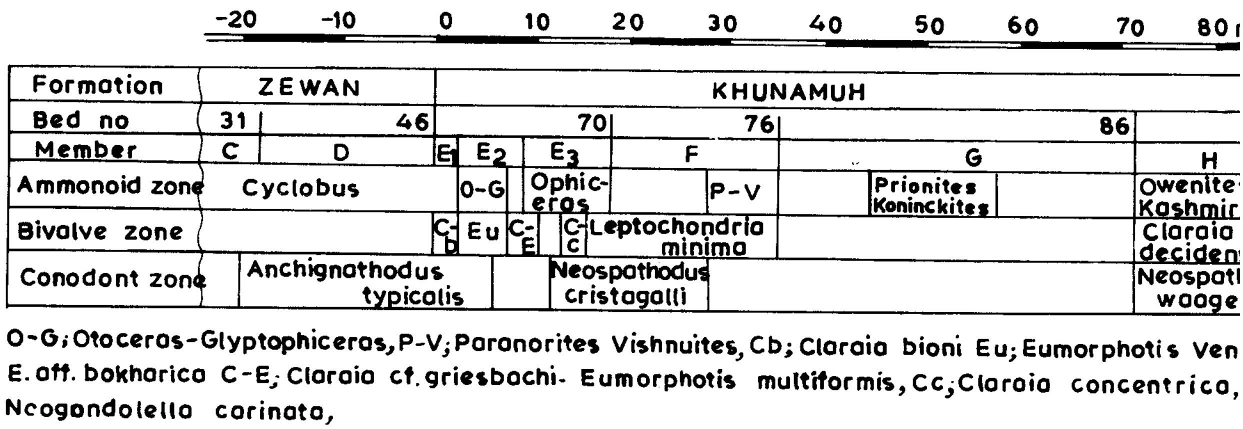

Figure 4- Ammonoid, bivalve and conodont zones in the section at Guryul Ravine, Kashmir (after Nakazawa **et al.**, 1975)

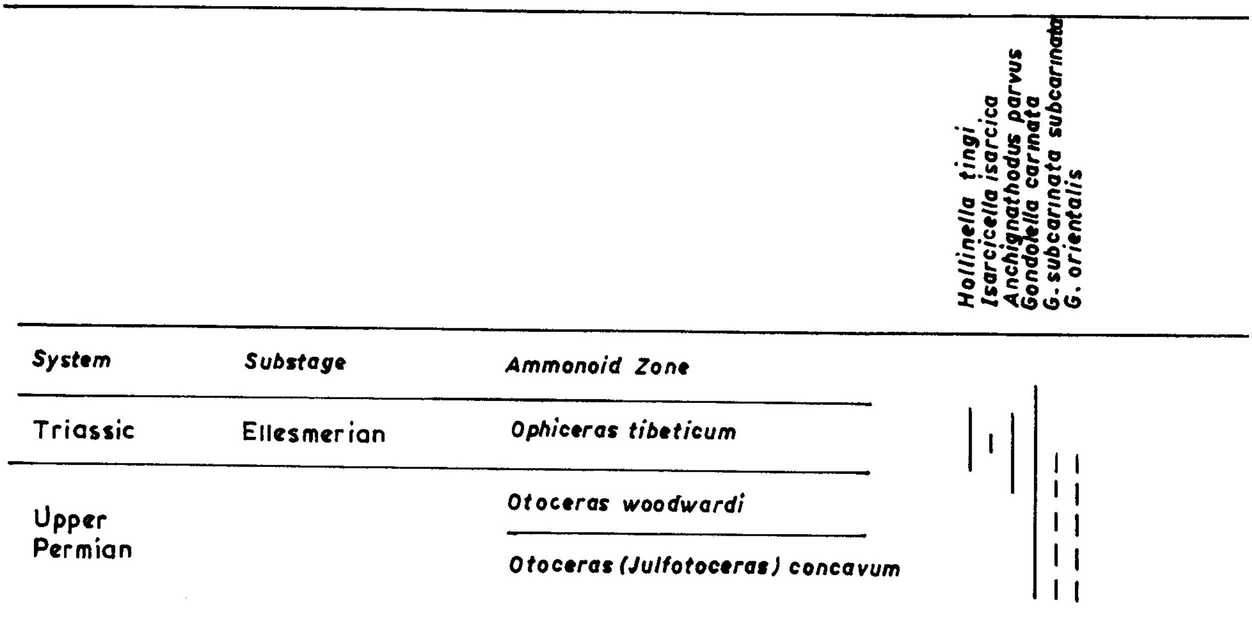

Table 4- Ranges of conodonts and *Hollinella tingi* in the *Otoceras woodwardi* and *O. (J.) concavum* Zones in the Himalaya.

the change of Palaeozoic ammonite faunas by those of Triassic which must trace the boundary between the Palaeozoic and the Triassic, occurred at the base of *Gyronites freguens* Zone [10].

Conodonts:

The systematic search for conodonts from different stratigraphic horizons of the Permian-Triassic succession exposed in different parts of Kashmir (Guryul Ravine and Pahalgam) and Spiti was made. During the sampling of the Guryul Ravine section, the results of Nakazawa *et al.* (1970,1975) including their lithostratigraphic divis were made for locating and detailed investigations o critical horizons for the study of conodonts. As sucl additional data obtained has been used to supplemen results already published by Nakazawa and Ka (1981).

The conodonts recovered from different stratigra levels of the Zewan Formation have not proved to b much stratigraphic value. Murata (1981) assignec upper part of this formation to the *Neogondo*

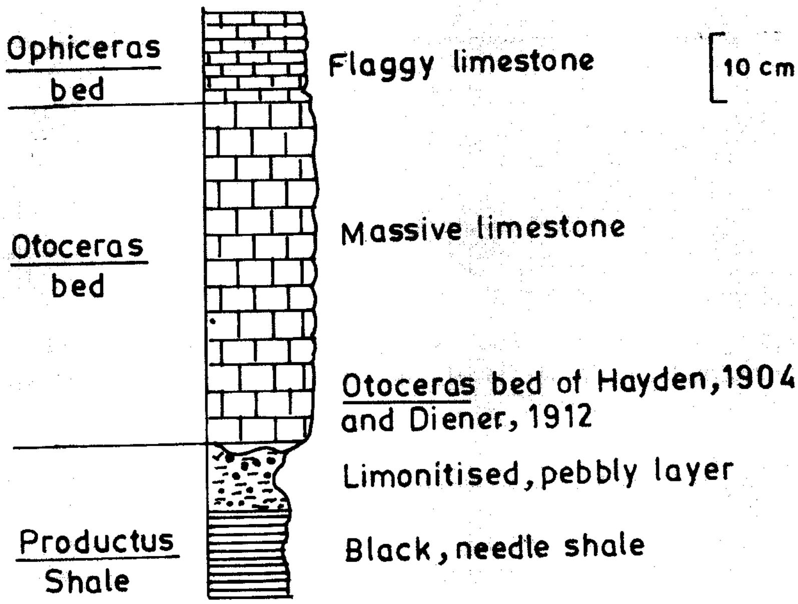

Figure 5- Permian-Triassic boundary beds in the Lalung section Spiti (after Bhatt **et al.**, 1981)

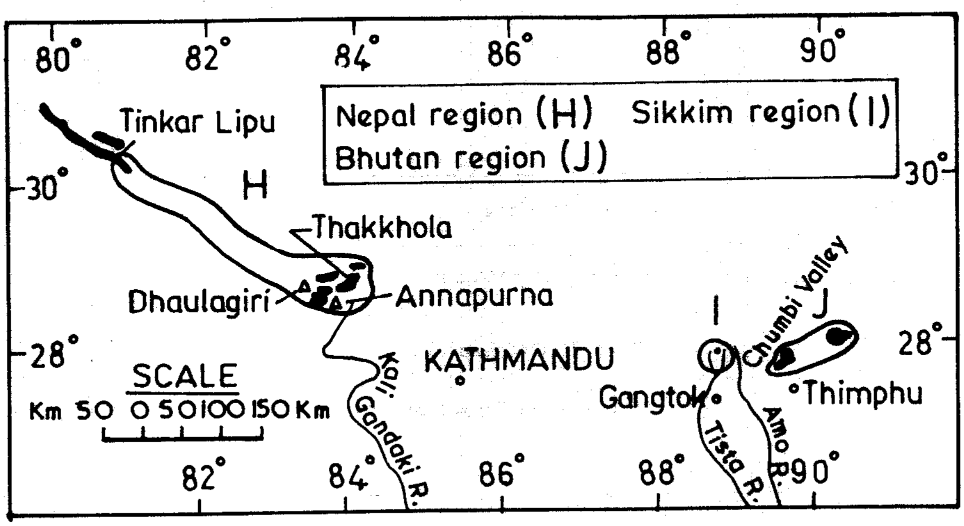

Figure 6- Sketch map showing distribution of Upper Permian and Triassic rocks (black areas) in parts of Nepal, Sikkim and Bhutan.

subcarinata subzone of *Anchignathodus typicalis* Zone. It may be pointed out that neither Murata (1981) nor his colleagues adduced any specific correlation or age to this conodont zone. *Anchignathodus typicalis* is known to occur in the upper 14 feet of the Chhidru Formation (now referred to as Landa Sandstone Member of Upper Djulfian age) and lowermost 3 to 9 feet of the Kathwai Member [53,54]. *Anchignathodus typicalis* is now regarded as having a very long time range by Kozur and Pjatakova (1976) and *Neogondolella subcarinat* considered to include various so-called species r from Capitanian into Early Triassic. This later vi not been accepted by Matsuda (1981) but he h provided any useful information regarding the range of *Neogondolella subcarinata* subzone.

Matsuda (in Kapoor and Tokuoka, 198 identified the presence of *Hindeodus mi* *Anchignathodus parvus* and *Gondolella carinata*

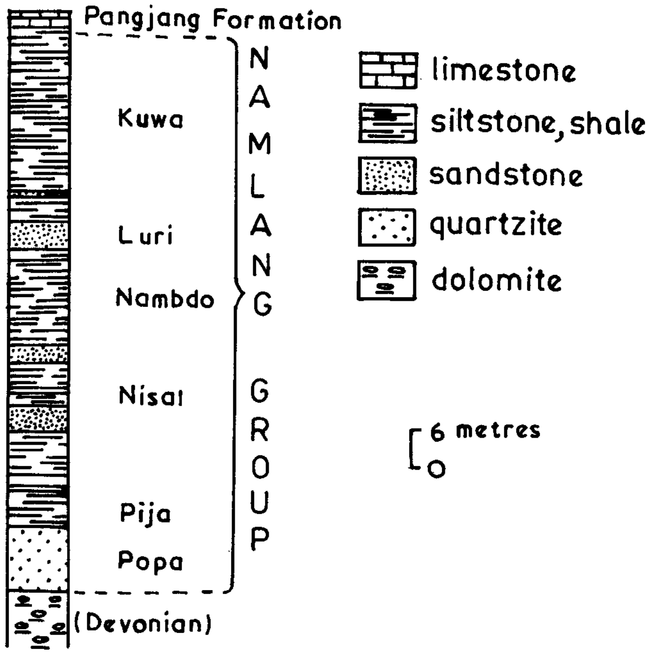

Figure 7- Permian formations and Permian-Triassic boundary in Dolpo region Nepal. Popa to Kuwa members belong to the Senja Formation of Permain Namlang Group (after Waterhouse, 1987).

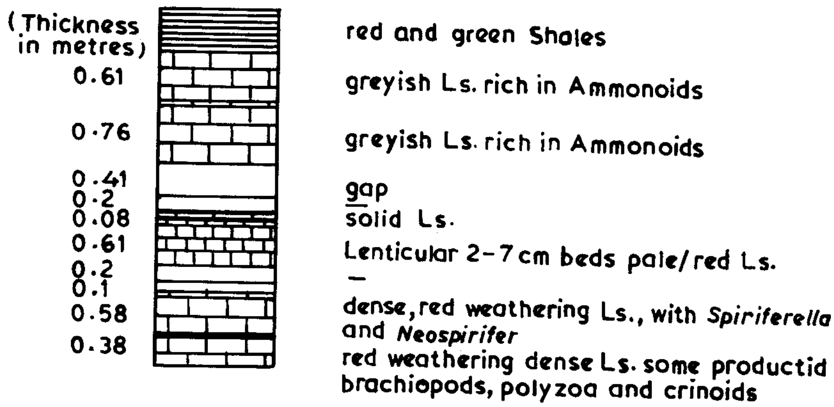

Figure 8- Detail of Pang Jang Formation exposed east of Thini Ridge, north of Thinkhola. The red and green shale at the top belongs to a separate unit. Ls=Limestone; Qtz=Quartzite; Sh=Shale; Ss=Sandstone (after Waterhouse, 1987).

upper part of the Th-IB section in Thakkola area of Nepal (Fig. 9). In addition to these, occurrence of *Kashmirella Kummeli* has also been recorded from Th-C section. The above mentioned conodont assemblages indicate Griesbachian age for the upper part of Th-B section and Dienerian age for Th-C section. According to Kapoor and Tokuoka (1985) the middle part of these sections (see Fig. 9) may correspond to Member A to B (or less probably A to D) of the Pangjang Formation [65] of Thinikhola section, (Nepal) and unit E-I of the Khunamuh Formation (Kashmir).

The detailed study of conodont material from varic parts of Kashmir and other regions of the Himala) has enabled us to establish additional conodont zor covering the Upper Permian to Dienerian interval. T newly established conodont zones have been defined the basis of detailed consideration of their features a succession of their respective faunas and these have be accurately located within the well-defined ammonc zones [10].

SERIE	STAGE	AMMONOID ZONES: CANADA (Tozer, 1967, emended by Dagis, 1985)	AMMONOID ZONES: TETHYS (Dagis, 1985)	PARALLEL CONODONT ZONES: NEOSPATHODUS ZONES (robust conodonts included)	PARALLEL CONODONT ZONES: KASHMIRELLA ZONES	PARALLEL CONODONT ZONES: NEOGONDOLELLA ZONES	CONODONT ZONAL STANDARD (Budurov et al., 1986, emend.)	STAGE	SERIES BOUNDARY
LOWER ANISIAN (part)					Kashmirella gondolelloides R.Z.	Neogondolella regale I.Z.	Neogondolella regale I.Z.	L. Anisian	
LOWER TRIASSIC	SPATHIAN	K. subrobustus "O". pilaticus	T. pakistanum (prohungarites)	Ns. triangularis - Ns. homeri I.Z.	Kashmirella gondolelloides R.Z. (cont.)	Ng. jubata I.Z.; Ng. shevyrevi R.Z.; Ng. taymirensis R.Z.	Kashmirella gondolelloides I.Z.; Ns. triangularis - Ns. homeri I.Z.; Ng. jubata A.Z.	SPATHIAN	
	SPATHIAN	?	Tirolites - Columbites	Parachirognathus - Platyvillous Furnishius; Spathoicriodus collinsoni R.Z.	?; Kashmirella spathi R.Z.	Ng. jubata I.Z. (cont.); ?	Spathoicriodus collinsoni I.Z.; Platyvillosus Beds	SPATHIAN	
	SMITHIAN	W. tardus	A. pluriformis M. gracilitatis	Parachirognathus - Platyvillous Furnishius; Ns. conservativus	Kashmirella albertii - Ks. novaehollandiae C.R.Z.	Ng. milleri R.Z.; Neogondolella buurensis R.Z.	Neospathodus waageni I.Z.; Ng. milleri R.Z.; Parachirognathus - Furnishius Beds	SMITHIAN	
	SMITHIAN	E. romunderi	F. flemingianus	Ns. waageni I.Z.	Ks. nepalensis R.Z.	Neogondolella buurensis R.Z. (cont.)	Kashmirella nepalensis R.Z.	SMITHIAN	
	DIENERIAN	V. svedrupi	Rotundatus - Volutus	Ns. dieneri - Ns cristagalli C.R.Z.	?		Neospathodus dieneri - Neospathodus cristagalli C.R.Z.	DIENERIAN	
	DIENERIAN	G. frequens	P. candidus	Ns. dieneri - Ns cristagalli C.R.Z. (cont.)	Ks. kummeli R.Z.	?	Ks. kummeli R.Z.	DIENERIAN	SUGGESTED P/T BOUNDARY (after Budurov et al., 1986)
	GRIESBACHIAN	P. strigatus	Oph. tibeticum	Anchignathodus — Isarcicella Beds		Neogondolella carinata I.Z.	Ng. carinata A.Z. ?; Isarcicella isarcica R.Z.	GRIESBACHIAN	
	GRIESBACHIAN	Oph. commune						GRIESBACHIAN	
	GRIESBACHIAN	Ot. boreale	Ot. woodwardi				Anchignathodus parvus I.Z.	GRIESBACHIAN	
	GRIESBACHIAN	Ot. concavum				Neogondolella subcarinata	Neogondolella subcarinata - Anchignathodus typicalis C.R.Z.	GRIESBACHIAN	TRADITIONAL P/T BOUNDARY
UPPER PERMIAN (part)								U.Permian	

Table 5- Parallel conodont zonation in the Lower Triasic and the Permian Triassic boundary (After [66]).

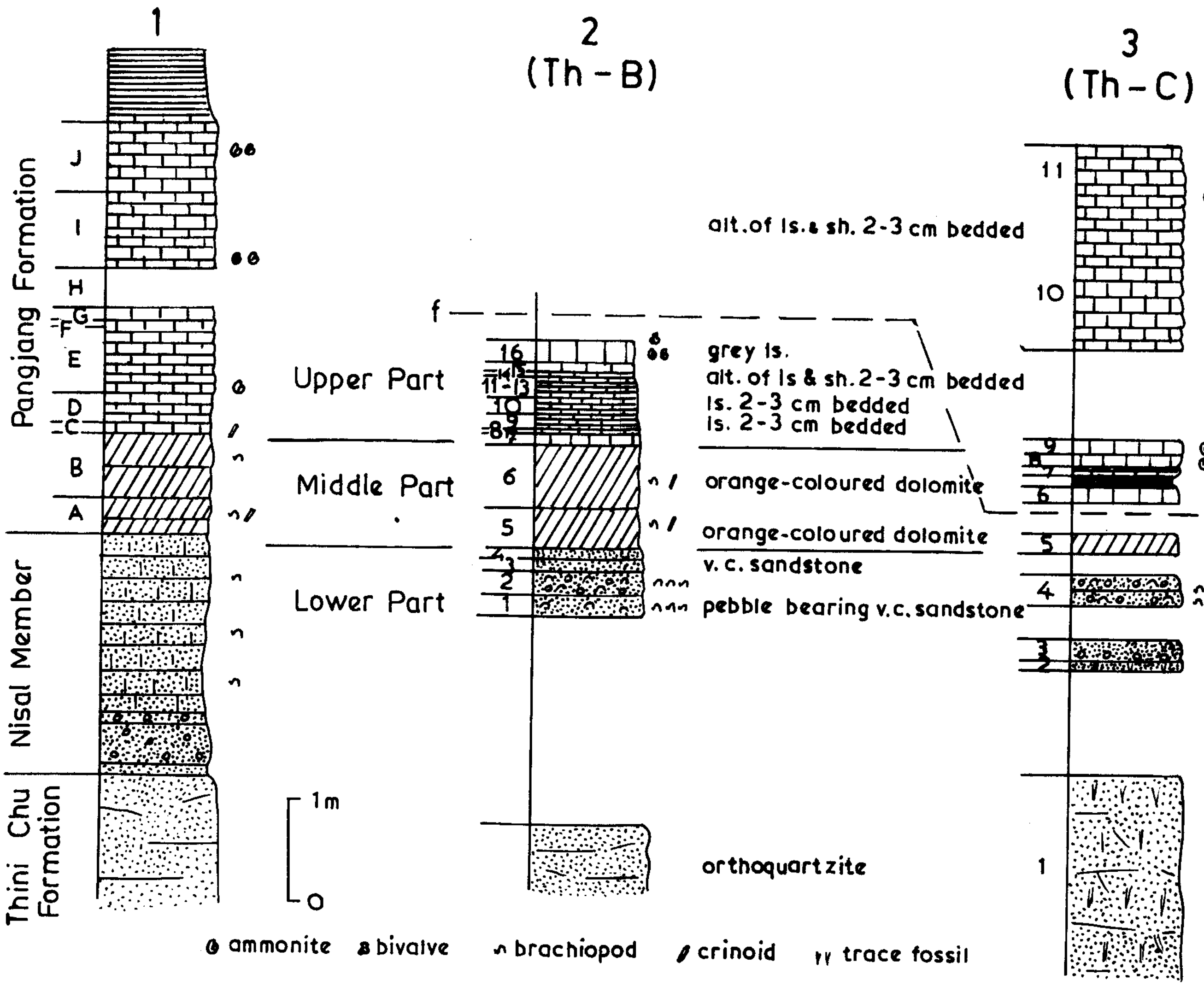

Figure 9- Permian -Triassic boundary at Thinikhola section, Thakkola area of Nepal (Column I, after Waterhouse, 1979; Column 2 (Th-B) and Column 3 (TH-C) from Tokuoka in Kapoor and Tokuoka, 1985).

The lower part of the Lower Griesbachian, corresponding to the basal units of the *Otoceras woodwardi* Zone, is relatively poor in conodont fauna and is characterized by the presence of *Anchignathodus typicalis* Sweet, *Neogondolella subcarinata* Sweet and *Neogondolella carinata* Sweet (*Neogondolella subcarinata-Anchignathodus typicalis* C.R.Z.). In Kashmir, the presence of these conodonts has been observed in Member D of the Zewan Formation and Units EI and E2 of Member E of the Khunamuh Formation. This is indicative of the fact that the *Anchignathodus typicalis* Zone has a very wide stratigraphic range and it may not serve any useful purpose. In contrast to this, *Neogondolella subcarinata* C.R.Z. has a very narrow stratigraphic range and defines the interval from the Upper parts of the Dorashamian to the lower parts of the Lower Griesbachian.

The upper part of the Lower Griesbachian (*Otoceras boreale* Zone) and the lower part of the Upper Griesbachian (*Ophiceras commune* Zone) is characterized by the presence of *Anchignathodus parvus* Kozur and Pjatakova. The lowermost part of the late Lower Griesbachian in Himalaya is marked by the occurrence of this species (excluding *Neogondolella subcarinata* Sweet) and corresponds to the *Anchignathodus parvus* I.Z.

The beginning of the Upper Griesbachian is marked

SERIES	STAGE	AMMONOID ZONES: CANADA (Tozer, 1967, em. by Dagis, 1985)	AMMONOID ZONES: TETHYS (Dagis, 1985)	CONODONT ZONAL STANDARD (Budurov & al., 1987, emend.)		SERIES BOUNDARY
EARLY ANISIAN (part)				Neogondolella regale I.-Z.		
EARLY TRIASSIC	SPATHIAN	K. subrobustus	T. pakistanum (Prohungarites)	Kashmirella gondolelloides I.-Z.		
		"Kz."pilaticus		Ns. triangularis - Ns. homeri I.-Z.	Ng. jubata A.-Z.	
					Spi. collinsoni I.-Z.	
		?	Tirolites - Columbites		Platyvillosus - Foliella Beds	
	SMITHIAN	W. tardus	A. pluriformis M. gracilitatis	Neospathodus waageni I.-Z.	Ng.milleri R.-Z.	
					Parachirognathus - Furnishius Beds	
		E. romunderi	F.flemingianus	Ksh.nepalensis R.-Z.		
	DIENERIAN	V. svedrupi	Rotundatus - Volutus	Neospathodus dieneri - Neospathodus cristagalli C.-R.-Z.		SUGGESTED P-T BOUNDRY (after Budurov & al., 1986)
		P. candidus	G. frequens	Ksh.kummeli R.-Z.		←
	GRIESBACHIAN	P. strigatus		Ng.carinata A.-Z. ?		
				Isarcicella isarcica R.-Z.		
		Oph. commune	Oph. tibeticum			TRADITIONAL P-T BOUNDARY
		Ot. boreale	Ot. woodwardi	Anchignathodus parvus I.-Z.		
		Ot. concavum		Neogondolella subcarinata - Anchignathodus typicalis C.-R.-Z.		
LATE PERMIAN (part)						←

Table 6- Conodont zonal standard and the possibilities of Permian-Triassic Periods or Palaeozoic-Mesozoic erathem boundary definition (*Ng=Neogondolella*) (After [13]).

by the presence of *Isarcicella isarcica* (Huckriede) and this corresponds to the appearance of *Ophiceras tibeticum* in Kashmir. The uppermost Griesbachian (corresponding to *Proptychites strigatus* Zone) is defined by the *Neogondolella carinata* A.Zone because it contains only forms of the conodont species of the same name.

The most important fact related to conodonts from Himalaya is the abrupt vanishing of faunas with *Anchignathodus* (including *Isarcicella*) at the Griesbachian/Dienerian boundary and the occurrence of Lower-Triassic blade-like conodonts which represent faunas of a totally different type. The base of Dienerian is defined by the first appearance of *Kashmirella Kummeli* R.Z. (Table 5). In addition, the Dienerian is also marked by the occurrence of several forms of *Neospathodus* falling within the *Neospathodus dieneri* - *Neospathodus cristagalli* C.R.Z. The striking change in conodont and ammonite faunas at the Griesbachian - Dienerian boundary most convincingly support the demarcation of Permian-Triassic boundary at this level (Table 6).

Conclusion

The Gungri Formation and its equivalents (Productus or Kuling Shales) exposed in different parts of Himalaya have yielded faunas supporting that the Punjabian Stage is certainly very widely present, the Djulfian with ammonoids towards the top, admittedly somewhat meagre, the Dorashamian with brachiopods very well represented, especially for the Vedian Substage in Nepal, and the Gangetian-Ellesmerian levels as classic examples.

The sedimentation during the major part of the Late Permian Period was principally marine. The Gungri Formation and its homotaxial in Himalaya have been considered for a long time to have been deposited in deep waters, especially the upper units yielding Cyclobids and other ammonoids. The amount of carbon present in the shales, and the fact that several faunal zones are missing, from between the beds yielding *Cyclolobus* and brachiopods belonging to the family comelicaniidae and overlying paraconformable *Otoceras* beds, suggest that the shales were deposited in very shallow waters of poor circulation and soft, muddy, poorly oxygenated bottom.

As discussed in the preceeding pages, the most widespread marine level of Himalaya is that of the *Lamnimargus himalayensis* Zone which was followed by *Otoceras -Ophiceras* faunas of the Griesbachian Stage. The Djulfian and Dorashamian sediments where present, are very thin and accumulated generally close to wave base [69]. Extremely shallow water transgression in Kashmir and Spiti basins provided very thin Late Permian sediments with some fossils, and slightly more substantial sediments, with comparatively rich faunas accumulated in northern Nepal, as in Armenia, Iran, Karakoram, etc. At the same time as these peculiar conditions of sedimentation prevailed over the Himalayas and much of the north, there was very little volcanic activity, suggesting a major cessation in sea floor spreading, allowing oceans to deepen and seas the recede from extensive continental shelves.

The upper stratigraphic limits of the *Otoceras woodwardi* Zone in different parts of the Himalayas can be fixed with the help of conodonts i.e. the first appearance of *Isarcicella isarcica*. The brachiopods recorded from the *Otoceras woodwardi* Zone support Permian affinities for this zone and it has been assigned Griesbachian age.

The base of *Ophiceras tibeticum* Zone corresponds to the base of *Isarcicella isarcica* R. Zone; the disappearance of *Otoceras*, Permian brachiopods and other holdovers. The base of overlying *Gyronites frequens* Zone corresponds to the end of the lowest faunal diversification and coincides with the Griesbachian-Dienerian boundary. This boundary is also marked by striking changes in conodont fauna from *Anchignathodus* and *Isarcicella* to *Kashmirella* and *Neospathodus*.

The available field evidences and analysis of micro- and macrofaunas from the *Otoceras woodwardi* Zone, *Ophiceras tibeticum* Zone and *Gyronites frequens* Zone support that the base of the *Gyronites frequens* Zone which coincides with the Griesbachian-Dienerian boundary, is the most befitting level for demarcating the Permian-Triassic boundary in the Himalaya.

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