



STRATIGRAPHIC NOMENCLATURE OF EARLY PALAEOZOICS IN THE SPITI HIMALAYA: COBWEBS CLEARED

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ABSTRACT

An avoidable controversy regarding the stratigraphic nomenclature of the Lower and Middle Palaeozoic formations of Spiti–Lahaul and Zaskar have been raised on poorly defined evidences and parameters particularly regarding terms Batal, Kunzam La, Thango and Takche, without valid facts to substantiate their claim. The argument that the Parahio valley is the type section of the Cambrian of India is extravagant. The Parahio is biostratigraphic type section only for the upper most part of Series 2 (Stage 4)—Wuliuan (Miaolingian Series). The Nigali Dhar Syncline with distinct prospect of delineation of Ediacaran–Cambrian boundary is the biostratigraphic type section for the Terreneuvian—Series 2. The present paper sets the record straight.

Keywords: Batal Formation, Kunzam La Formation, Thango Formation, Takche Formation, Spiti, Himalaya,

INTRODUCTION

In recent years, inadvisable and avoidable controversies have been pushed into the domain of stratigraphic nomenclatures of some of the Tethyan sequences in the Himalaya (Myrow et al., 2006; Suttner, 2007; Hughes et al., 2018). This is more due to limited and hurried traverses taken by geologists and consequent lack of appreciation of regional geological setup established by rigorous regional geological mapping carried out in India, particularly in the Geological Survey of India, on modern 1:50,000 toposheets based on the lines suggested by the Code of Stratigraphic Nomenclature of India. Controversies, though add a spice and make a debate exciting and productive, it gets tasteless and insipid when it becomes irrational and biased. The aim of this paper is to focus on problems of stratigraphic nomenclature in the proper perspective.

Before the merits/demerits of controversial lithostratigraphic terms are discussed, it is necessary to mention in brief the rules of nomenclature of formations as enumerated in the Stratigraphic Code of nomenclature India (Anon. 1971)

1. A Formation should be mappable on the regional scale the country has adopted. In our case it is 1:63360 scale (earlier British System Toposheets) or 1:50000 scale (Metric System Toposheets) currently in use.
2. Lithostratigraphic unit should be independent of fossil content and inferred geologic history. *‘Nevertheless, fossils may be used merely for descriptive purpose as any other lithologic constituent, but without time connotation, in defining a lithostratigraphic unit.’* (4.03 p. 3).
3. Mapping is based on detailed Lithostratigraphic Classification, with top and bottom criteria precisely defined.

After examining vast area, and after selecting an ideally exposed field section, suitable name after a locality, where full and best available section is exposed, be adopted. Ideally, naming after a river or Highway which cuts through several formations is avoided.

It must always be appreciated and remembered that creating or naming a formation imposes a need for a detailed lithostratigraphic mapping and not merely a casual traverse along couple of sections.

In a vast terrain like the Himalaya several geoscientists might have mapped smaller areas and given local and ad-hoc names. To avoid multiplicity of names, the earliest suggested names are adopted with proper scrutiny. However, these local names are not always based on sound principles of stratigraphic classification and nomenclature to arrive at a uniform nomenclature. Thus, this principle of adopting the earliest suggested name cannot be applied indiscriminately. The name should be selected from those which fulfill the aforesaid first three criteria of the Code of Stratigraphic nomenclature. In this context the Indian Code specifically mentions, *“Earlier established stratigraphic units and their nomenclature, if unable to stand the test of the code, are to be classed as informal. Use of such terms should normally be avoided and replaced by formal nomenclature. Further, these informal names should always be placed within inverted commas or parentheses, if at all they are to be referred to”* (3.01, p, 2).

For example, Capt. Palmer, while taking a traverse along Mashobra to Tattapani in the Shimla Hills named the sequence exposed in this part as “the Mule Track Series”. It was abandoned and replaced by Simla Slates (Pilgrim and West, 1928).

TERMS THAT NEED CRITICAL ANALYSIS

In the early history of evolution of stratigraphic terms in India, the British geologists working in the Geological Survey of India, many of them well versed in geological work and possessing great wisdom introduced the concept of lithostratigraphic classification though the nuances of such a classification had not taken firm footing and the tendency was more on the lines of chronostratigraphy and some biostratigraphy. There are several lithological units with multiple names in Indian stratigraphy. However, to dissect many of these names, we need to bring out a volume. In the present paper we deal with only three, particularly in the Tethys Himalaya, which have caused avoidable confusion and unwarranted turbulence in the data base of lithostratigraphic classification broadly encompassing the Cambrian, Ordovician and Silurian sequences of the Tethyan Himalaya. Further, it should be realized that the Tethyan belt of the Himalayan Tectogen is a continuous belt from Kinnaur-Spiti-Lahaul in SE to Zaskar and beyond to Ringdom Gompa in NW and beyond

to Sanko in Suru Valley, as established by systematic mapping on 1: 50,000 scale base map. It is remarkable that all the major geological formations, based on lithostratigraphic classification, are continuous and clearly identifiable by any student of Geology.'

Babeh Series (Cambrian succession) in the Spiti and Zanskar:

Stoliczka (1865) described the rocks exposed at the Babeh Pass in the Central Himalaya of Spiti as the Babeh Series (*Spelling as per stratigraphic lexicon*) consisting of sandstones, slates and quartzites probably of Silurian age, which in wider sense included Ordovician and much of Cambrian. Perhaps, this was the first attempt to assign a name for a lithological unit in Spiti.

Haimanta System

Subsequently, Griesbach (1891) included the Babeh Series in his expanded **Haimanta System**, which he regarded as the Cambrian and probably also as part of pre-Cambrian for the reason that much of the rocks of this system largely developed in the snow-clad Central Himalayan Mountains. The Haimanta is shown to succeed the pre-Cambrian Vaikrita System.

Hayden (1904) classified the Cambrian in Spiti (Table 1). He divided the Cambrian rocks of the Parahio valley in 18 beds with seven fossiliferous levels. Hayden (1904), however, did not use the term Babeh and also refrained from formally naming the Cambrian succession of the Spiti Valley. The Babeh Series thus became an obsolete name.

Parahio Series

The Parahio Series is an enigmatic term in the Stratigraphy of Spiti. Hayden never referred to this term in his Memoir (1904). Six years after the publication of Hayden's 1904 Memoir, Reed (1910), a noted Paleontologist, chose the term Parahio from which area he had studied the fossils earlier collected and sent by Hayden, but Reed himself had not visited the Spiti Valley and had no idea of regional distribution of rocks. Based on fossils collected by H. H. Hayden, he designated (or more correctly

baptized !!) the fossiliferous part ('c' of Hayden, 1904) as the Parahio Series and divided it into three stages (Reed, 1910).

This task of naming the formation should have been that of Hayden, if he were convinced of the suitability of Parahio being the type section and not that of Reed (1910).

Pascoe (1959) followed Reed (1910) in continuing with the name Parahio for the beds that *are said to pass up gradually* from the upper siliceous beds of the Upper Haimanta System, which would correspond to 'c' of Hayden. Pascoe (1959) incorrectly attributed the term to Hayden (1904).

The term Parahio was thus used only for the upper most part of the Cambrian, with no firm criterion to define the base of the formation. The confusion is apparent.

The "Parahio Series," which was used only for a part of the Cambrian, thus, is improperly defined, and is being imposed on scientific community (Hughes *et al.*, 2018 and references therein). Originally, it was restricted to the sequence resting over the Upper Haimanta (Hayden, 1904; Pascoe, 1959). Hayden (1904) was aware that the Middle and Lower Haimanta were not exposed in the Parahio Valley, hence did not mention these. The section in the Parahio Valley is thus, truncated and *incomplete*. The term 'Parahio' whether as series or formation is obsolete.

New Lithostratigraphic Classification Haimanta Group and its formations:

Srikantia *et al.* (1976) while mapping the Spiti and Zanskar areas, (Srikantia, 1977; 1981) re-designated the Haimanta System as the Haimanta Group, divisible into three regional formations Batal, Kunzam La and Thango. The Batal is the basal formation with its characteristic black green pyritous, carbonaceous phyllite, and interbedded quartzites locally purple phyllite, quartzites, local conglomerates and lenticular limestone in the Zanskar sector. Some sporadic trace fossils are seen. The Batal is the most visible formation extending upto Ringdom Gompa. There are several smaller plutons and boss of granite intruding the Batal Formation

Srikantia (1981) divided the Kunzam La Formation in five members viz., A, B, C, D and E- developed in the Batal-Kunzam La stretch and also in the Batal-Chandra Tal section. These formations have been traced by Srikantia *et al.* (1976,1980) and Srikantia (1981) from Spiti right up to the west-northwest of Zanskar, where the Kunzam La develops thick dolomitic limestone facies with characteristic brown coloured weathering. Bhargava and Bassi (1998) separated the Thango Formation from the Haimanta Group owing to an angular unconformity observed at its base. In Kinnaur too, the redefined Haimanta Group has been identified and mapped on 1:50,000 scale (Bassi, 1989)*.

Nanda and Singh (1977) in strike continuation in the Zanskar area termed the Cambrian rocks as the Phe Formation. The term Phe was also used by them for the Permian volcanic rocks (Phe Volcanics) thereby, violated the code of stratigraphic nomenclature (Nanda *et al.* (1978).

The Phe Formation, also included equivalent of the Batal Formation (Nanda and Singh, 1977), hence is ill-defined and

Table 1. Classification of Cambrian in the Spiti by Hayden (1904)

Subdivisions	Lithology	Thickness
(c)	an upper, fossiliferous series of slates, quartzite and dolomites, only the lowest beds of which have been found in the areas examined by previous observers	about 1200 feet.
(b)	a middle subdivision, consisting of bright red and black (ferruginous and carbonaceous) slates, with some quartzite; this is well developed in the Pin, Parahio and Thannam valleys, and presumably corresponds to Mr. Greisbach's upper Haimantas	about 1,000 feet.
(a)	a series of dark slates and quartzite, corresponding to Mr. Greisbach's middle Haimantas	2,000 & 3,000 feet

*Incidentally it may be mentioned that Srikantia carried out the Geological mapping in Parahio in Spiti and Lahaul sectors in 1973, submitted a report to the GSI and a paper based on this work to the Editor *Geologische Rundschau*; the editor of the Journal kept the manuscript with him without any action on it and did not care to respond also. Finally, Srikantia requested Late Prof. A. Gansser when he met him at Moscow for International Ophiolite Conference to enquire into it and only on his intervention, the manuscript was returned to Srikantia stating that they did not find any person to review it!!!, thereby denying Srikantia of his priorities.

with improper terminology. Incidentally, Horton *et al.* (2015) considered the Phe Formation in the Zaskar region as part of the Higher Himalayan Crystalline, below the South Tibetan Detachment System.

Hughes and his associates initially used the term Kunzam La (Jell and Hughes, 1997; Hughes and Jell, 1999) and the Phe Formation for the sequence containing the Cambrian trace fossils (Hughes and Droser, 1992), but switched to Parahio in subsequent publications (Myrow *et al.*, 2006a, 2006b; Peng *et al.*, 2009; Popov *et al.*, 2015; Hughes, 2016a, 2016b; Hughes *et al.*, 2013; 2018; Gilbert *et al.*, 2016). Hughes *et al.*, (2018) made four observations that need mention: (a) the Babeh Series cannot be accorded priority as it contained sequence other than the Cambrian (b) the existence of the Batal Formation is suspect. Though Hughes *et al.* (2018) doubted the existence of the Batal Formation, yet Myrow *et al.* (2016a, 2006b) had described the “Parahio Formation” to overlie more metamorphosed and deformed, shale-rich strata of the Phe (Zaskar) and Batal (Spiti) Formations, (c) based on single zircon date the rocks close to the Batal bridge have been considered equivalent of the rocks exposed in the Parahio valley *i.e.* the Unit “c” of Hayden, (d) though the base of the “Parahio Formation in the Parahio valley is not exposed being truncated by a fault (Bhargava *et al.*, 1982), yet to justify the Parahio valley as the type section Hughes *et al.* (2018) cited American Code of Stratigraphic Nomenclature that it was not necessary to have the base of a sequence exposed in the type section, (e) that Parahio is the type section of the Cambrian of India.

DISCUSSION

- (a) The name Babeh is unacceptable to Hughes *et al.* (2018) as it contained sequence other than the Cambrian, yet the name Parahio used initially only for a part of sequence above the Upper Haimanta is acceptable and applied for the entire sequence, despite the sequence in the Parahio valley being incomplete (see in sequel); we find it a curious combination of twisted logic and bias,
- (b) Hughes *et al.* 2018 (fig. 4, p. 6) reproduced an incomplete cross-sectional profile of Hayden (1904), which suppresses Unit 1 (thick succession of sediments lying above the granites) and part of 2 of Hayden (1904), Fig.1 reproduced here from Hayden (1904) clearly shows succession No.1 (Cambrian slates and quartzite altered by contact with igneous rocks), which is equivalent to the Batal Formation of Srikantia (1981). The Batal Formation is not a local tectonised unit as visualized by Hughes *et al.* (2018). It is the most recognizable regional formation underlying the

Kunzam La Formation in Lahaul–Spiti and Kinnaur areas (Srikantia, 1981 Bassi, 1989; Bhargava and Bassi, 1998), and further, it has been traced by mapping from Lahaul to Zaskar and beyond upto Ringdom Gompa where it is overlapped by Permian Phe Volcanics (Srikantia *et al.*, 1976, 1978). It reappears at Sanko in Suru Valley. Its equivalent is also known in the Kashmir basin as the Machhal Formation, measuring +725 m (Shanker *et al.*, 1989). The Batal and Kunzam La Formations are closely associated. In some sections as in Spilo (Kinnaur) the rocks of the Batal Formation have a minor discordance with the underlying Vaikrita Group. At places, particularly along the contact between the Batal and the gneissic rocks of the Vaikrita Group, tectonisation and disharmonic folding are noticed. In the main Padam Valley of the Zaskar along the southern dip-slope gneisses underlie the Batal rocks along a steep dip-slope. In many sections these sediments are welded to the basement. The Batal Formation, in the basal part, comprises grey-green phyllite, grey quartzite, pyritous carbonaceous phyllite and minor gritty conglomerate layers and locally lenticular limestone bands. Sporadically, migmatites and paragneisses with garnetiferous biotite schist are also present in the section between Tandi and the Biling Lungpa in South Lahaul. In the middle part of the sequence the Batal Formation is composed of quartzite alternating with pyritous carbonaceous phyllite forming the dominant lithology and is well exposed in the section between the Biling Lungpa and Keylong. The upper part of the Batal Formation, exposed between Keylong and Darcha, comprises green coloured chlorite phyllite, carbonaceous phyllite, quartzose phyllite with interstratified pale white to grey quartzite, which becomes dominant between Istingri and Kwaring *nala*. South of Lolang and Munchi Shama in Lahaul 75 cm to 1 m thick bands of gritty to pebbly quartzite are exposed. Good exposures of the Batal rocks are present in the Chandra valley. The Manjir and Katarigali Formations of the Chamba Basin are equivalent of the Batal Formation with which they link up in the Chamba area.

The rocks of the Batal Formation exhibit rippled layers, lenticular bedding and local graded bedding of limited thickness indicating a peritidal, partly inter-tidal setting in somewhat poorly circulated basin. The basin gradually shallowed and got aerated. There is a general paucity of sedimentary structures, though the stratification is clearly identifiable. Locally cross-stratification of thin sedimentation unit and ripple marks is present. The litho-assembly suggests a mixed environment of broad peritidal condition.

- (c) The beds at the Batal bridge cannot be equivalent of the Parahio section (unit 3 of Hayden). The sequence containing carbonate beds near Shitikar in the Kunzam La section is equivalent of

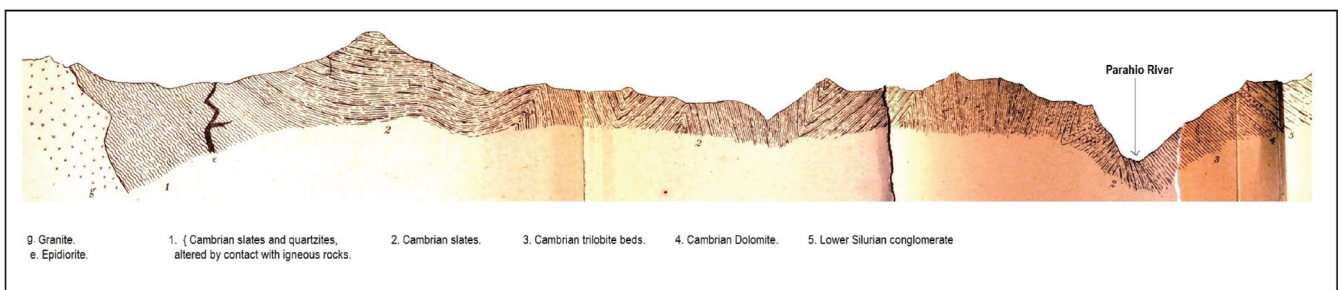


Fig. 1. Part of section of Hayden (1904) reproduced to show Cambrian sequence exposed in the proper Parahio valley.

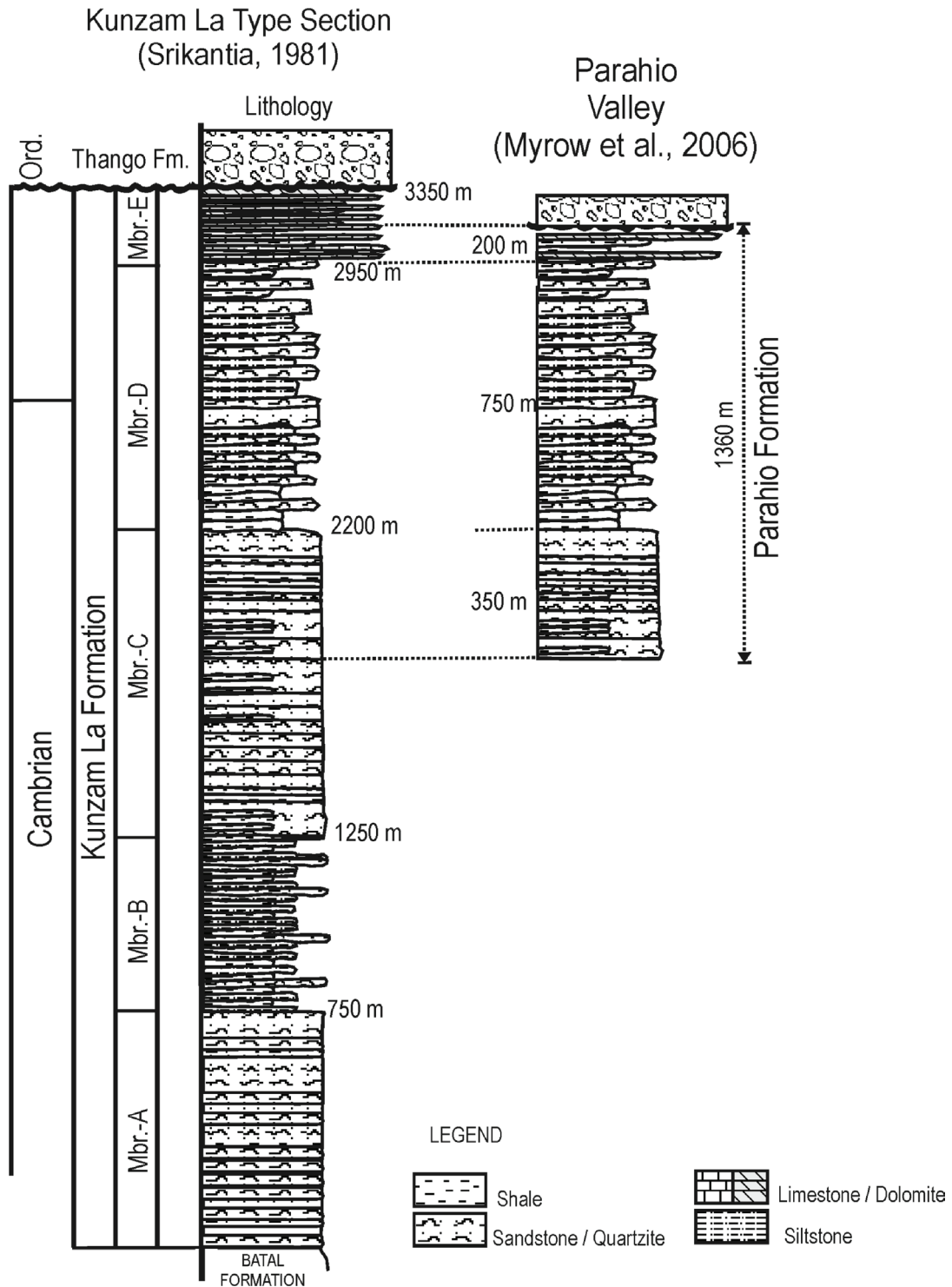


Fig. 2. Columns of the Cambrian to show sequence in the Kunzam La and Parahio valley; it clearly shows that only a part of the Cambrian succession is exposed in the Parahio valley. A fault exists at the base of the, "Parahio Formation" of Myrow *et al.* (2006), thereby truncating the sequence in the Parahio valley.

Parahio section. The rocks near the Batal Bridge occur more than 1000 m below the Shitkar sequence, hence could not be equivalent of the Parahio section. Either the location of the sample is wrong or the 524 Ma age based on a single grain analysis (Myrow *et al.*, 2003, 2010) is due to contamination and is, therefore, doubtful.

(d) Citing American Code of Stratigraphic Nomenclature to

justify an incomplete section to be type section is a bad analogy. Will they accept our application of Indian Code to redefine some American formations?

(e) The Parahio valley cannot be considered as the type section for the Cambrian as it is incomplete as the erosion has not gone deep enough to expose the older part and also its lower part is truncated by a fault (Fig. 1). Hayden, (1904, Pt.I,

Pl.I) showed a huge thickness of the Cambrian strata (No.1 to No. 3, Fig. 1) in cross-sectional profile, of which only a part of No. 2 and partially No. 3 to No. 4 are exposed in the Parahio valley, which were described as fossiliferous parts of the Cambrian in the Parahio valley and were designated as the Parahio series by Reed (1910). Succession No. 2 (Cambrian slates) is equivalent to the members A-C of the Kunzam La Formation (Srikantia, 1981). Recent work indicates that Member C of Srikantia (1981) contains abundant traces of the *Treptichnus pedum* zone, *Cruziana tenella* zone and member D contain *Psammichnites gigas* zone in the Kunzam La-Chandra Tal region (Kaur *et al.*, *in review*); indicating Stage 2 to Stage 3 rocks which have not yet been recognised in the Zaskar-Spiti region. *Psammichnites gigas* zone is also recorded in the Parahio and Sumna valleys (Hughes *et al.*, 2013; Bhargava *et al.*, 1987; Kaur *et al.*, *in review*) and in the Lesser Himalaya (Singh, 2011; Singh *et al.*, 2014; Hughes, 2016). The strata No. 3 is equivalent to the Members D-E of Srikantia (1981), which alone is well preserved in the Parahio valley (Fig. 2). The thickness of the Kunzam La sequence according to Wiesmayr and Grasmann (2002) in the Spiti region is more than 6000 m. whereas it is merely 1369 m in the Parahio valley (Myrow *et al.*, 2006a, b) while it exceeds 1900 m in Zaskar (Myrow *et al.*, 2006a, b). The section in the Parahio valley is least developed and incomplete; this aspect is best depicted in Fig. 2. Though the Parahio section is good for the upper most part of Series2 (Stage 4)—Wuliuan (Miaolingian Series, old Middle Cambrian) biostratigraphy; but the biostratigraphy and lithostratigraphy are neither synonymous nor interchangeable. A formation has to be named after a locality where full section is exposed.

Thus, the claim by Hughes *et al.* (2018) that the Parahio is the Cambrian type section of India is extravagant; it is the type section only for the upper most part of Series 2 (Stage 4) —Wuliuan (Miaolingian Series), the Nigali Dhar section in the Lesser Himalaya with distinct prospect of delineating the Ediacaran—Cambrian boundary and the Chandra Tal section with excellent trace fossil biostratigraphy are the biostratigraphic type sections for the Terreneuvian—Series 2 (lower Cambrian).

In their Fig. 2, Hughes *et al.* (2018) dropped the term Batal Formation without any explanation / justification and also did not provide the type section of the Phe Formation as conceived by them, which is quite different as originally defined by Nanda and Singh (1977), and prove its mapability. The Karsha Formation, originally described by Nanda and Singh (see their table, 1977) represented red quartzite, grit and assigned to Ordovician age, was a mix up of upper part of the Kunzam La and the Thango Formations. The newly conceived Karsha Formation by Hughes *et al.* (2018) is mappable only in small part of the Zaskar and certainly not in the Spiti. Similarly, the Kurgiakh Formation is mappable in small part of the Zaskar and not even recognizable in the Spiti or Kinnaur. These should be assigned, if at all, only a member status. In fact, the Karsha is equivalent of the 'Parahio series' of Reed (1910), which was designated as one of the members of the Kunzam La Formation (Kumar *et al.*, 1984)

It is curious that ill-defined terms have been adopted in preference to well defined, extensively mapped and referred in the text books.

Which term to adopt?

Which term should be adopted: Parahio or the Kunzam La? The following facts eloquently speak for themselves:

Parahio name was not used by Hayden (1904) who had regionally mapped the Spiti Valley. Later, it was used only for the sequence resting over the Upper "Haimanta" and was never meant to cover the entire "Haimanta system" (Reed, 1910; Pascoe, 1959). Subsequently, the Parahio series was designated as the Parahio Member of the Kunzam La Formation (Kumar *et al.*, 1984). The sequence in the Parahio valley is incomplete (Fig. 2) and tectonically truncated, hence does not qualify to be the type section.

To extend the term Parahio to embrace the entire Cambrian succession, which was originally neither intended nor is justified, as the complete Cambrian sequence is not exposed in the Parahio valley, violated the Indian Code of Stratigraphic Nomenclature. Complete succession of the Kunzam La Formation of Srikantia (1981) is exposed in the Kunzam La section (Fig. 2); it is entirely lithostratigraphic and contains the fossiliferous horizons of the Cambrian.

Myrow *et al.* (2006a) opined "The base of the Parahio series was considered conformable with the underlying red and black slate, with quartzite beds assigned by Pascoe (1959) to the upper part of the Haimanta series. Pascoe's lithological description of the Parahio series provides an accurate description of these beds, and the term has historical precedence as a lithostratigraphic name. Accordingly, we formally herein designate Pascoe's Parahio series as the Parahio Formation, with the type section described in this paper. The Parahio Formation includes the entire section of the Parahio Valley rocks described herein, with its top defined here by the unconformity and its base defined by the first occurrence of trace fossil-bearing strata. Rocks of the underlying Batal Formation are devoid of carbonate beds, excepting in some places in Zaskar gritstone and lenticular limestone are associated with carbonaceous phyllites (Srikantia *et al.*, 1978) and trace and body fossils, although an acritarch assigned to *Anguloplanina* has been recorded from the uppermost part of this formation, (according to Kumar *et al.*, 1984)." Myrow *et al.* (2006a) statement, "The base of the Parahio series was considered conformable with the underlying red and black slate, with quartzite beds assigned by Pascoe (1959) to the upper part of the Haimanta series."— is a misquote. Pascoe (1959) placed the Parahio series above the Upper Haimanta and not as a part of Upper Haimanta. Definition of the base of the Parahio at the first occurrence of trace fossils by Myrow (2006a) is *flawed*. Fossils cannot be used to define the lithostratigraphic boundaries, as these may not be found in all the sections, particularly the trace fossils, which are facies controlled. The trace fossils, if at all, may appear at different levels in different sections thus making mockery of the precision in lithostratigraphic boundary. Enough of argument has been adduced with facts about the untenability of the term Parahio in previous paragraphs. Pascoe (1959) has based his study on the lithological input of Hayden (1904) and for the nomenclature he depended on Reed (1910). It may be re-emphasized that (a) prior to Parahio the term Babeh existed, (b) neither Reed (1910) nor Pascoe (1959) used the term Parahio for the entire Haimanta/Cambrian (almost 4000 feet thickness), but only for a sequence resting over the Upper Haimanta and (c) the section in the Parahio Valley is incomplete/truncated. (d) The fossiliferous part alone does not constitute the basis of lithostratigraphic classification !

Hughes *et al.* (2018) have argued that Parahio is the type section for the Cambrian of the India. Srikantia (1981) identified five members of his Kunzam La Formation in the Kunzam La section, of these only the upper two viz., D and E are exposed

Table 2. Classification of Ordovician-Silurian succession in the Pin Valley by Goel and Nair (1977).

Muth quartzite passing gradually into	110-245 m
Unnamed quartzite—transitional to:	25 m
Unnamed siliceous and flaggy limestone-Llandovery	20 m
Thanam limestone (new name)	15 m
----Late Ashgill or Llandovery coral fauna	
PIN LIMESTONE (NEW NAME)	
Unit 4-Shaley limestone with nondescript fauna	10m
Unit 3-dolomitic and siliceous limestone with shale	12 m
Unit 2-limestone weathering brown	10 m
Unit 1-dark foetid limestone with shaley Lst, shale bands	80 m
Shian quartzite (new name)	

in the Parahio Valley section (Fig. 2) alongwith little of C. Hayden's section unambiguously shows that only a part of Unit 2 is exposed in the Parahio valley, which as stated above is incomplete on two counts: the erosion has not gone deep enough and also the section is truncated by a fault as accepted by Myrow *et al.* (2006a) also. How could this incomplete section be the type section?

Even biostratigraphically, the Parahio is the best section only for the upper part involving trilobites, trace fossil biostratigraphy part is not fully developed in the Parahio section and its best development is in the Kunzam La-Chandra Valley section. In the Parahio valley section complete parts of the Beds 1 and 2 of Hayden are not exposed (Fig. 1). Hayden's Bed 3 alone is trilobite bearing. Hughes *et al.* (2018) have placed Karsha Formation above the "Parahio Formation" and well

below the Shian Formation (=Thango), which is arbitrary as the Karsha Formation as per Nanda and Singh (1977) represents red quartzite, grit of Ordovician age, which is reminiscent of the Thango Formation. Obviously, there is quite a bit of ambiguity and the term cannot be adopted.

Hughes *et al.* (2018) have doubted the existence of the Batal Formation. The Batal Formation corresponds to unit 1 of Hayden (1904), (Fig.1), which is in contact with the granites/crystallines. The rocks near the Batal bridge from where Myrow *et al.* (2003, 2010) sampled for the detrital zircon age are indeed part of the Kunzam La Formation, as Srikantia (1981) mentioned that Batal Formation is exposed between the Chota and Bara Dara localities in the Chandra valley. At the Batal Bridge, the Kunzam La Formation is exposed and not the Batal Formation, but it cannot be equivalent of Unit 3 of Hayden (1904) as discussed above. The mapability of the Kunzam La Formation has been established from Zanskar to Kinnaur over an aerial distance of more than 150 km, whereas the Parahio as originally defined by Reed (1910) has not been mapped even beyond the Parahio valley.

Besides numerous research articles (for detailed references see Bhargava, 2008, 2011; Parcha and Pandey, 2011, 2016) and in all the textbooks totaling nine, term Kunzam La has been adopted, thus it is well entrenched in the literature (Kumar, 1982; Sinha, 1989; Negi, 1998; Vaidyanadhan and Ramakrisnan, 2006; Chakrabarti, 2016, Valdiya, 1998; 2016; Raju, 2017; Shah, 2018, Roy and Purohit, 2018). Trying to replace a term well-entrenched and well defined in the literature is least to say irresponsible, and will be confusing to students and researchers.

The entire controversy is due to Hughes *et al.* (2018) clearly confusing between the lithostratigraphy and biostratigraphy,

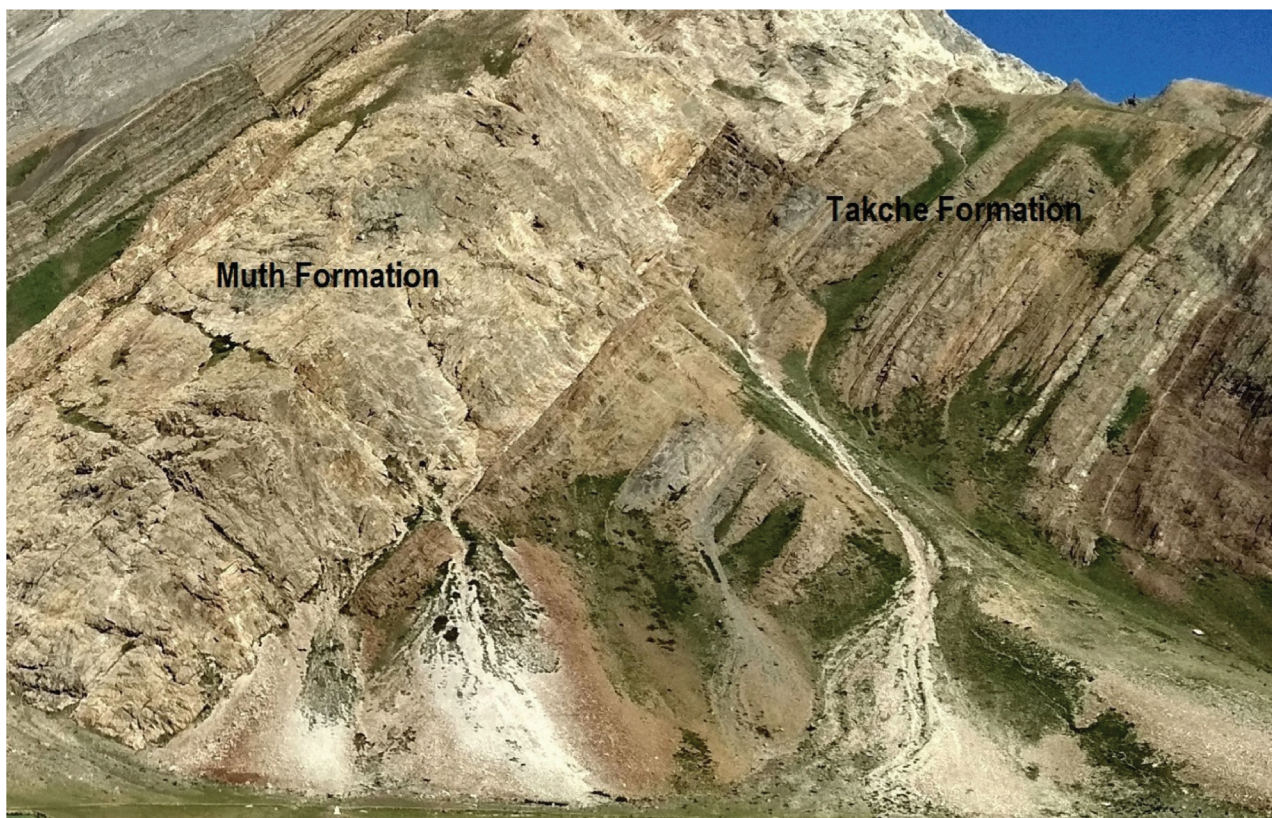


Fig. 3. Sharp and disconformable contact between the Takche and the Muth Formations.

Hayden, 1904	Srikantia et al., 1976	Goel & Nair, 1977	Suttner, 2007
Muth Quartzite	Muth Formation	Muth Formation	Muth Formation
Ordovician-Silurian limestone	Takche Formation	Unnamed quartzite	Pin Formation
		Unnamed siliceous & flaggy quartzite	
		Thanam limestone	
Ordovician Conglomerate and quartzite	Thango Formation	Shian quartzite	Shian Formation

Fig. 4. Classification of Ordovician-Silurian succession in Spiti by various authors.

while deciding that the Parahio is the best section. The lithostratigraphic nomenclature is based on lithostratigraphic components and not fossils. The latter forms basis for biostratigraphy, and biostratigraphy is relevant only when tied with the lithostratigraphy.

Thango, Karsha, Shian in Spiti and Zaskar regions:

Srikantia *et al.* (1976, 1978; Srikantia, 1981; Srikantia and Bhargava, 1998) proposed Thango Formation for a sequence above the Kunzam La Formation and below the Takche (discussed in sequel). The Thango Formation was identified and mapped in Kinnaur also (Bassi, 1989).

Goel and Nair (1977) proposed Shian Quartzite as a new name. It was just a name with no lithologic and top-bottom details (Table 2) and of course, never mapped.

Nanda and Singh (1977) in the Zaskar area proposed Karsha Formation, it lacked details and did not include conglomerate so very characteristic of the sequence.

Which term to adopt?

The name Shian appears only in a Table (cf. Hughes’s *et al.*, 2018, comments on Srikantia’s *et al.*, 1977) and is devoid of lithologic details, and top and bottom criteria, as per clause 3.01 is violative of the Stratigraphic code (p, 2), had a still birth. Still it has been used by Myrow *et al.* (2016) and now by Hughes *et al.* (2018) instead of well-defined and extensively mapped Thango. However, the term Thango was also used in several publications by Hughes group (Hughes and Droser, 1992; Jell and Hughes, 1997; Myrow *et al.*, 2006a, 2006b; 2009; 2010, Peng *et al.*, 2009; Popov *et al.*, 2015; Gilbert *et al.*, 2016).

Description of “Karsha” and “Shian” was incomplete, thus Thango is the only term which is valid and conforms to the criteria defined in Indian Stratigraphic Code and for obvious

reasons referred to in most of the publications, including the text books referred above.

Sequence between Thango and the Muth Formations (Takche, Pin, Thanam, Thaple in Spiti and Zaskar)

Srikantia *et al.* (1976, 1980; Srikantia, 1977, 1981) proposed the term Takche Formation for the sequence above the Thango Formation and below the Muth Formation. The Takche Formation has been mapped on 1: 50,000 scale from Zaskar to Kinnaur (Bhargava and Bassi, 1998). This formation has variable thickness owing to pre-Muth erosion (Bhargava and Bassi, 1998).

Goel and Nair (1977) proposed ‘Pin Limestone’ and ‘Thanam limestone’ (Table 2), for a sequence above what they termed as the “Shian quartzite”. These two “Limestone sequences” with quartzite etc., equaled the Takche Formation of Srikantia *et al.* (1976; Srikantia, 1981). Though, Goel and Nair (1977) provided lithological details, there were several ambiguities: (a) their sequence commences with Bed 2 of Hayden (1904) having ignored the Bed 1 of Hayden (1904), (b) ‘Muth quartzite’ has a sharp disconformable contact (Fig. 3) with the underlying sequence (Bhargava and Bassi, 1998) with the absence of late Silurian and ?early Devonian. The limestone sequence does not pass gradually into Unnamed quartzite transitional; ‘Unnamed siliceous and flaggy limestone’ as mentioned by Goel and Nair, 1977), and (c) the mapability of these two formations as mandated by the Stratigraphic Code was neither proved nor is individually possible.

Nanda and Singh (1976) used the term Thaple resting above the ‘Ordovician Karsha Formation’ and below the ‘Kenlung Formation’ (=Muth Formation), which included equivalents of Pin and Thanam formations, and possibly part of the Thango Formation thus is vague and inappropriate.

Suttner (2007), Hubmann and Suttner (2008), Suttner and Ernst (2007), Suttner *et al.* (2005, 2007), Schallreuter *et al.* (2008), and Myrow *et al.* (2016), however, ignored the Takche Formation of Srikantia *et al.* (1976) and Thanam Limestone of Goel and Nair (1977) and extended the term Pin “for the entire sequence between Thango and the Muth Formations, when the term Takche defining this sequence already existed and mapped between Zaskar and Kinnaur and which like the Kunzam La and Thango Formations finds place in all the text books referred above.

What is more arbitrary and irrational in making Takche (Fig. 4), which is an extensively mapable unit developed between the Thango and the Muth formations as a member of the “Pin Formation” which *sensu stricto* (Goel and Nair, 1977) constituted the lower part of the sequence between the Thango and the Muth and was not mapable. Also, creation of a new Mikkim Member (Suttner, 2007) is aberration as unit is not exposed at Mikkim and a similar sounding formation existed in the Triassic sequence of Spiti (Mikkim). Relegating Takche, which covered the Pin and Thanam Formations and has been mapped from Zaskar to Kinnaur, to a member level is violative of the Stratigraphic Code and tantamount to spreading stratigraphic anarchy. A more reasonable scheme would have been: Takche Formation divisible in Farka Muth, Pin and Thanam Members

Which term to adopt?

Only the Takche Formation conforms to the specifications of the Indian Code of Stratigraphic Nomenclature.

CONCLUSIONS

The above narration makes it more than obvious that the use of Parahio, Shian and Pin lacks justification:

The genesis of this Parahio-Kunzam La controversy can be traced to Reed (1910), who made otherwise a valuable paleontological contribution in the Parahio valley, though he did not have the knowledge of ground geology of the terrain. He, however, proposed the name Parahio to the section from which the fossils were collected and sent to him for detailed study on behalf of Hayden. This name is being perpetuated by workers (Hughes *et al.*, 2018).

The present authors, in the interest of Earth science, suggest that all the earth scientists follow standard norms according to the Stratigraphic Code of India and refrain from tweaking the well-established nomenclature. The task of naming a formation should be left to mappers who see a vast area and identify the best section.

Parahio term was never used by Hayden (1904), the mapper of the Spiti Valley. The Parahio Series was different from the Haimanta 'System' and was placed above his Upper Cambrian fossiliferous section by Hayden (1904). Pascoe (1959) following Reed (1910) and, that the section at the Parahio Valley is an incomplete section as realized by Hayden (1904) and Pascoe (1959) who do not mention Middle and Lower Haimanta in their schemes. Also, Parahio's bottom still not defined and mapability not proved. As suggested earlier it could be at best adopted as a member of the Kunzam La Formation if at all necessary. Hence, we reject the term "Parahio Formation" and uphold the status of the well tested Kunzam La Formation.

Shian lacks all the essential ingredients as required by the Stratigraphic Code and should have never been adopted. Thus, we reject the term "Shian Formation" and uphold the status of the Thango Formation.

The term Pin represents only a part of Ordovician-Silurian siliciclastic carbonate sequence, is neither representative nor mappable as defined by Goel and Nair (1977) and Suttner (2007) and Suttner *et al.* (2007). The Pin and Thanam may be adopted as members of the Takche Formation. We reject the term "Pin Formation" and uphold the status of Takche Formation.

The terms Kunzam La, Thango and Takche have been prolifically used in all the text books published, hence deeply entrenched in the literature and this is what the students read. In the light of this, it is perfectly within the right of Indian authors to use terms which are widely adopted in the text books rather than violating the stratigraphic code of nomenclature of India.

The statement of Hughes *et al.* (2018) that the Parahio is the Cambrian type section of India is misleading, it is a biostratigraphic type section only for the upper most part of Series 2 (Stage 4)—Wuliuan (Miaolingian Series). For the Terreneuvian—Series 2, the Nigali Dhar section with distinct prospect of delineating Ediacaran—Cambrian boundary is much better qualified.

ACKNOWLEDGEMENT

One of the author ONB thankfully acknowledges the contingent grant of Indian National Science Academy, New Delhi, India.

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Manuscript received : August 2018

Manuscript accepted : October 2018

