

CAMBRIAN BIOFACIES AND FAUNAL PROVINCES OF HIMALAYA *

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ABSTRACT

Provincialism in Cambrian trilobites has been recognized from early times when three realms viz. Pacific, Atlantic (Acado-Baltic) and Australo-Asian "provinces" were identified. With additional faunal data from all parts of the globe, problems have arisen about the boundaries of these realms as also about the distribution of some cosmopolitan elements. For a satisfactory model of endemism, the palaeogeography, palaeolatitudes and magnafacies are some of the main operative variables. Most of the faunal realms identified on a global basis show commingling of fauna at one level or another. It is, therefore, imperative to study the fauna at identical stratigraphic levels since the pattern is bound to change across time. The Himalayan Cambrian has been considered as enigmatic for trilobite provincialism in Middle and early Late Cambrian times since the fauna of Spiti-Zaskar basin does not correspond with that of Kashmir although they lie in the same geographic realm. The biostratigraphic and faunal data from Himalaya, generated in recent years, affords an opportunity for testing the existing models of Cambrian provincialism and evolving a concept. This has been attempted whereby different faunal elements at the generic level have been analysed on the bases of their palaeoecological and palaeogeographical distribution.

PALAEOBIOLOGY AND FAUNAL PROVINCIALISM

The discoveries of Cambrian trilobites in various parts of the globe towards the beginning of the present century revealed a pattern which intrigued stratigraphers. Even in sections within the same geographic setting the fauna at apparently identical stratigraphic levels did not correspond. This extreme degree of endemism, defying all concepts of present day geographic provincialism, led to the postulation of varying explanations, a process which continues to this day, following the enormous expansion of data base. It has become clear now that there is no single line of evidence that can provide a comprehensive explanation. Several theories of provincialism have floundered on the rocks of Cambrian.

It has to be accepted that faunal and floral provinces identified from time to time are results of a necessity to generalize and are seldom based on empirical studies. Though periodic attempts have been made at quantification there is no agreed basis for quantitative recognition of the degree of endemism necessary for identifying different biogeographic realms, regions, provinces and sub-provinces. In fact even the classification itself, if loosely applied, carries an element of subjectivity about it. This is true for a single time plane like the present day. When the time element is introduced as an additional dimension, the picture becomes murkier.

In spite of these impediments, it has to be admitted that during the last two decades we have obtained a better appraisal of the limiting barriers and gradients that can operate on the marine fauna, on all scales, from the local ecological level to the climatic and oceanic realm level. This has generated a plethora of terminology. In the absence of a clear understanding and because of imperfect data on palaeoecology and palaeogeography, most of these terms are vague. In fact even the common and well defined terms like "realms", "regions", "provinces" and "subprovinces" in the modern biogeographic sense are used interchangeably and sometimes synonymously in palaeobiogeography. This handicap has to be accepted with the existing state of knowledge about Palaeozoic in general and Cambrian in particular.

EVOLUTION OF THE CONCEPT

Before dwelling on the subject of Cambrian provincialism, it would be necessary to trace a brief history of the evolution of ideas in this regard. In the first half of the present century three "provinces" (realms in the modern sense), recognized for Cambrian (mainly for Early and Middle Cambrian) viz. Pacific, Atlantic (Acado-Baltic) and Australo-Asian, were thought to be produced due to land barriers which were considered as main causes of endemism at that time. The concept of the three "provinces" was proposed by Grabau (1910) and adopted with some modifications

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by Gregory and Barrett (1931). However, none of these "provinces" could be clearly demarcated since they had a hazy boundary and, as further data poured in, commingling of the fauna could be seen in several areas. The analysis of these data indicated that the provincial distribution appeared to be a result of the accident of first discovery rather than a geographic isolation or purity of the fauna. Lochman-Balk and Wilson (1958) produced a model on the biogeography of North- American Cambrian sequence based on the distribution of trilobite fauna at the generic level, which emphasized the role of palaeoecological and tectonic control as the basis of endemism. However, this model stumbled on the application of geosynclinal classification and terminology, which was very popular during those days, and this robbed it of much of its relevance. Nevertheless, the theory that biofacies and lithofacies constitute empirical factors for endemism formed the seed of the modern magnafacies concept. The latter emerged after a series of studies undertaken through IGCP and Cambrian Subcommittee of IUGS.

The concept of provincialism in Early Cambrian was revised by Cowie (1971) by identifying the main "provinces" and suggesting the channels of migration and commingling of faunas. However, none of these identified realms bore a fauna completely exclusive to each. There is overlapping of faunas in Morocco, Siberia, England, North-west Greenland and California to name the most prominent examples. In order to account for the isolated niches of endemic elements and the aberrant commingling, depth, water chemistry and the nature of the sedimentation were considered as factors additional to palaeogeography.

Shallow water and deep water environments as responsible for trilobite provincialism was a hypothesis developed by several workers, notably Taylor (1976). He further elaborated that differences in temperature and temperature stability between warmer shelf and colder adjacent slope habitats were among the more important factors that differentiated these provinces. The concept that the unrestricted access to open oceans and restricted access due to carbonate barriers or environmental parameters causing provincialism (Palmer, 1969, 1973, 1979) also came to be accepted.

During the last two decades, palaeomagnetic studies have acquired a distinct application in determining the cause and mechanism of endemism since they provide data on the palaeolatitudes and appar-

ent polar paths of palaeocontinents. Cambrian trilobite provinces have since been related to palaeolatitudes (Cowie, 1971; Palmer, 1972; Ross, 1975; Ziegler *et al.*, 1981). It has provided explanations for a series of enigmatic faunal similarities and differences. It also helps in evaluating the pattern of ocean surface currents which could explain palaeoclimatic anomalies and helps in the identification of climatically sensitive taxa. On the basis of these data, biogeographical maps showing the distribution patterns of the better known taxonomic groups have been prepared for each period of Palaeozoic Era (Ziegler *et al.*, 1977). There are, however, some basic constraints to the palaeomagnetic data and the palaeogeographic maps based on them. The data do not provide any useful information on longitudinal distances and thereby the true extent of the palaeocontinents and oceans or the correct east to west order of the continents. This is where biogeography coupled with palaeolatitudinal data provides clues about precise continental positions, as in many cases provinces are shared by more than one palaeocontinent and this places some limits on longitudinal separation.

PROBLEMS RELATED TO PALAEOBIOGEOGRAPHIC ANALYSIS

Before dwelling on the relevance of the faunal realms in palaeogeographic context of Himalaya, it would be imperative to address ourselves to some basic questions related directly or indirectly to provincialism of faunas in the distant past in general and Cambrian in particular. These could be briefly posed as under:-

1. Theories on provincialism derive sustenance from the present day distribution of fauna which is undoubtedly related to geography, ecology, climate and a number of other smaller factors. Most of these factors in the distant past would be related to global tectonic evolution. The latter becomes hazy as we proceed backwards in time, and Cambrian is pretty ancient for that purpose. For example, if we go by the ocean floor spreading concept we have a scenario in Cambrian when there may have been hardly any oceans in the modern sense. How do we superimpose the present day concept of provincialism to such a scenario?
2. In trilobites we are dealing with a group which is extinct and the life history of which can be pieced together only from moulted off carapaces of different ontogenic stages.

While some modern arthropods, like marine crustaceans, may be taken as paradigms for their habitat, they would not provide any vital information necessary for analysing provincialism of benthic or nekto-benthic organisms e.g., length of pelagic larval life, if any. How far could the habitat, inferred from functional morphology determined from a paradigm, be considered as reliable?

3. What should be the taxonomic level for a quantification of provincialism? Theoretically it should be the species since that is deemed to constitute an "interbreeding population" or a geographic entity. But how can we take care of subjectivity in speciation especially in extinct groups where genetic basis of morphology is doubtful? It is not uncommon among taxonomists to name different taxa on the basis of their distribution rather than morphology.
4. While analysing present day provincialism we are dealing with a single time plane. A similar analysis is valid in past only if we deal with a single time plane or nearly so. A longer time span would create several complications. As an example an endemic taxon in a single time plane could transgress provincial boundaries or become cosmopolitan in a longer time frame depending on its dispersal potential. How can this waxing and waning of provincialism in time be quantified?

These questions and several others crop up while attempting generalizations in demarcating the provinces either qualitatively through the evaluation of significant faunal "communities" or quantitatively by Jaccard and Simpson coefficients and equations. Understandably no biogeographer can afford to fall hopelessly in love with any theory of provincialism, however attractive it may be. At best he can flirt with it till a better alternative becomes available for that purpose.

FAUNAL PROVINCIALISM IN HIMALAYAN CAMBRIAN

Many Cambrian biostratigraphers recognize four realms in shallow water magnafacies namely American, Siberian, European and Hwangho (Palmer, 1973, 1979; Jell, 1974; Taylor, 1976; Chang 1980) although all of them do not use the same nomenclature. In the deep water magnafacies there is no unanimity about the various realms but two or three realms are generally identified. In all these classifications the Himalay-

an Cambrian has been left out. The only publication where the distribution of Himalayan Cambrian was considered on the pattern of Lochman-Balk-Wilson model (1958) is that by Wakhaloo and Shah (1965). The Cambrian fauna of Himalaya was always considered enigmatic at best and poorly recorded at worst. The latter may have been true upto the sixties of the present century but is no longer so as a wide variety of taxa from measured sections in Himalayan Cambrian in Kashmir, Spiti, Zaskar and Garhwal have since been listed and described (Shah, 1973, 1982; Shah and Paul, 1987; Shah and Sudan, 1982, 1983, 1987a, 1987b; Shah *et al*, 1980, 1985, 1988; Jell, 1986; Whittington, 1986; Kumar *et al* 1987). It becomes imperative that the fauna from these basins from selected stratigraphic levels be analysed. The identification of such levels has been the main hurdle since in the various Himalayan basins there are few identical taxa. Except for *Redlichia* in Early Cambrian and some agnostids, eodiscids and a couple of polymerids in Middle Cambrian-early Late-Cambrian there are hardly any common trilobite taxa between Kashmir and Spiti-Zaskar, even at the generic level. The brachiopod and ichnofossil taxa are of little value in time correlation upto the degree of precision that is necessary for identifying such levels. Only three significant levels can be identified for the purpose of this analysis viz. *Redlichia* (Early Lenian), *Pagetia-Ptychoparia* (Late Solvan-Early Menevian) and *Diplagnostus-Damesella-Cyclolorenzella* (Late Menevian-Early Maentwrogian).

The approach to the analysis is two-fold, i.e. the evaluation of intrabasinal and interbasinal endemicity and the determination of the degree of provinciality at the inter-provincial level. The analysis has been attempted only at the generic level to avoid the element of subjectivity in speciation. Three major factors governing provinciality have been considered as primary ignoring other minor factors for which no data are available at present. These comprise magnafacies, palaeogeography and palaeolatitudes. The exercise is entirely qualitative and based on the known occurrence only. The analysis has been undertaken only for *Pagetia-Ptychoparia* level and *Diplagnostus-Damesella-Cyclolorenzella* level, since the *Redlichia* level contains very few trilobite taxa and includes the characteristic genus of Australo-Asian realm for which only the geographic control seems to be operative.

All the trilobite genera reported from Himalaya at these two levels have been listed and their global distribution determined. This distribution has been

plotted on a palaeolatitudinal map for Late Cambrian (after Scotese *et al.*, 1979). The pattern of distribution is not uniform and it has been evaluated within the framework of the three factors mentioned above. The distribution has also been related to the functional morphology of the taxa to verify if the relevant factor could be operative. The taxa have been thereafter grouped according to the control that appears to be operative in each case. The distribution and grouping for the two levels is indicated in figs. 1 and 2.

The results can be briefly summarized as under:

1. There is a waxing of provinciality at the Solvan-Menevian Stage and waning at the Menevian Maentwrogian Stage.
2. The depth and accessibility to the open sea/ocean constitutes an important factor for most of the taxa at Solvan-Menevian level and accounts for the higher degree of intra-provincial endemism.
3. Palaeolatitudinal control is restricted to shal-

low water taxa and this appears to be a reflection of the climatic restraint in the palaeotropical region.

4. Only deeper water taxa are cosmopolitan or constitute forms characteristic of a whole realm or region.
5. Geographical control renders majority of the faunal elements provincial. However this control is generally transgressed by the magnafacies producing anomalous "faunal islands".

Three questions, however, demand an answer:-

1. Why are the bulk of trilobite taxa listed from Kashmir different from those of Spiti-Zaskar, even at the generic level?
2. Does the Himalayan fauna constitute a single province?
3. Can the Himalayan provinces fit in a bigger realm or does it constitute a realm by itself?

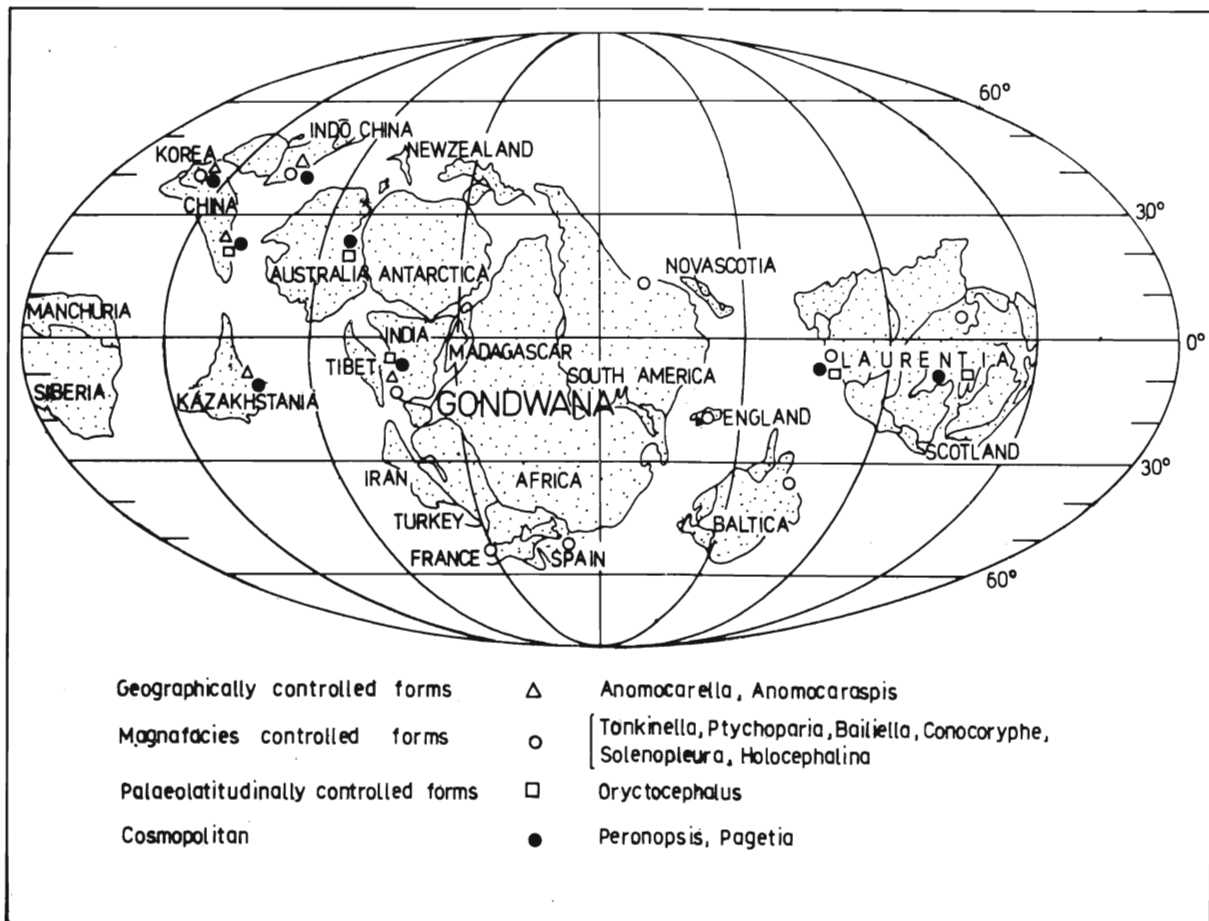


Fig. 1. Distribution of Himalayan Middle Cambrian fossil taxa (Palaeolatitudinal map after Scotese *et al.*, 1979).

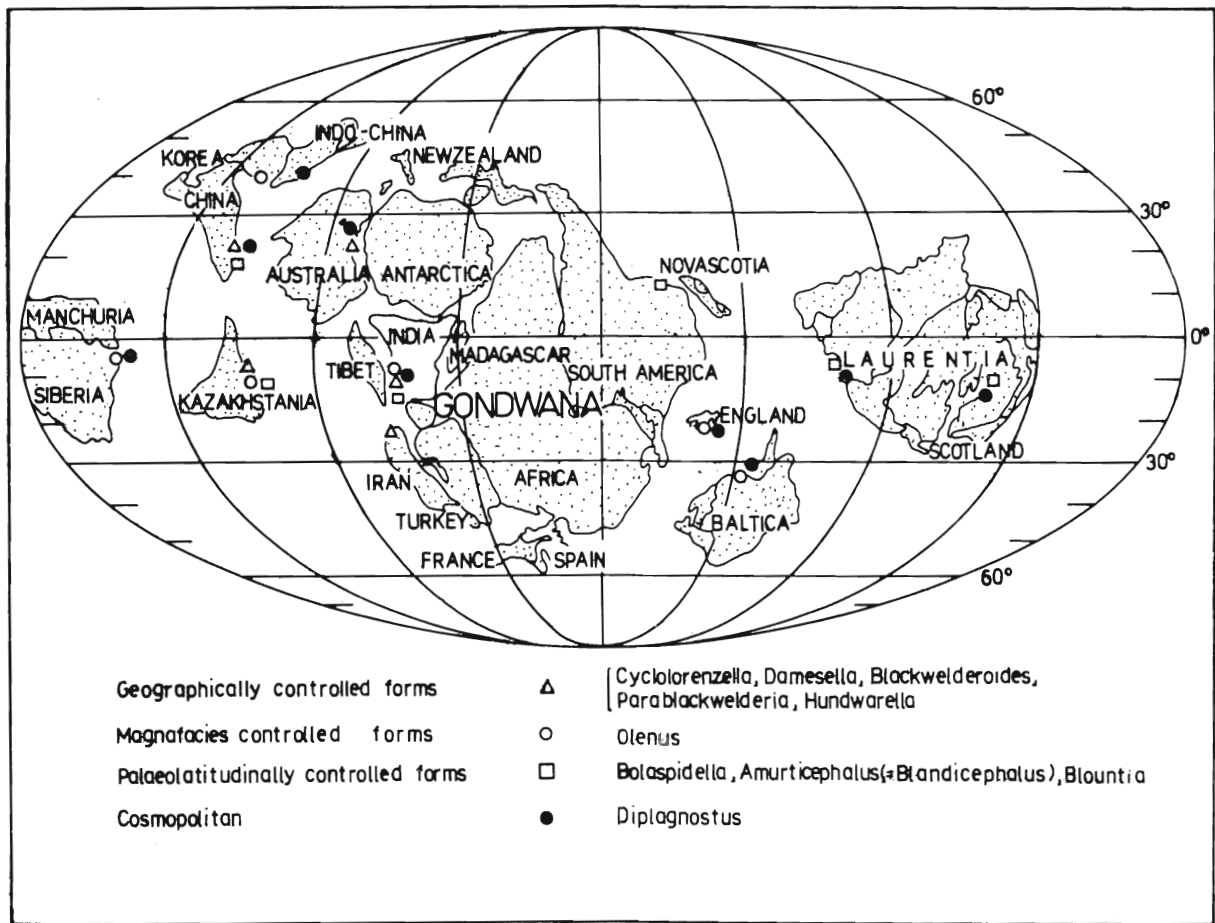


Fig. 2. Distribution of Himalayan Late Middle and Early Late Cambrian fossil taxa (Palaeolatitudinal map after Scotese *et al.*, 1979).

Within the limitations of palaeobiogeographical modelling, as discussed earlier, it may be possible to attempt an answer to the first two questions. But for the cosmopolitan genera *Peronopsis*, *Pagetia* and *Solenopleura* and the regional form *Hundwarella*, there are hardly any genera common to Kashmir and Spiti-Zanskar in Middle Cambrian (Solvan-Menevian). Likewise in early Late Cambrian (Maentwrogian) only two taxa viz. *Cyclolorenzella* and *Diplagnostus* are common to the two areas. The hypothesis proposed by some authors that the fauna has been tapped at different stratigraphic levels in the two areas is no longer tenable. The significant common elements mentioned above allow for a time correlation. Moreover, except for *Hundwarella*, there is a total absence of evolutionary lineages among the different genera across the two areas, which should have been manifest if they represented parts of the same province and magnafacies at various chrono- stratigraphic levels. The factors responsible for the difference appear to be those governing magnafacies variation viz. an inner

detrital belt of light coloured terrigenous sediments and a carbonate platform in Kashmir and an outer detrital belt of dark or black silty and shaly sediments in Spiti-Zanskar. Some amount of palaeolatitudinal control is also discernable for the shallow water forms of Middle Cambrian. Whatever the factors, there is no escaping the fact that they are parts of different "provinces" which are not geographically controlled. The provincialism wanes towards the end of Middle Cambrian due to the gradual deepening and possible access to open sea, while the conditions in Spiti-Zanskar allow for the presence of only deep water taxa at this level, unlike those in Kashmir where in addition to deep water taxa shallow water forms persist.

The answer to the third question would be a corollary to the first two. In the geographical sense they do constitute a realm which could be a part of a larger one including Australia and possibly Iran. However, there is a limited inter-migration of fauna (mostly cosmopolitan forms) across the ecological

barrier between the two. But when comparisons with Australian fauna on one hand and fauna of Iran, Afghanistan and Kazakhstan on the other hand are attempted there appears to be an intra-continental diversity and inter-continental similarity. Would this mean that in Middle and Late Cambrian between Kashmir and Spiti-Zaskar we are at the boundary of two realms? A lot more empirical data from all these areas would be needed before attempts can be made to answer that question.

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