



LATE MIDDLE AND UPPER CAMBRIAN  
BIOSTRATIGRAPHY AND FAUNAL PROVINCES  
OF HIMALAYA

BY  
ALOK KISHORE

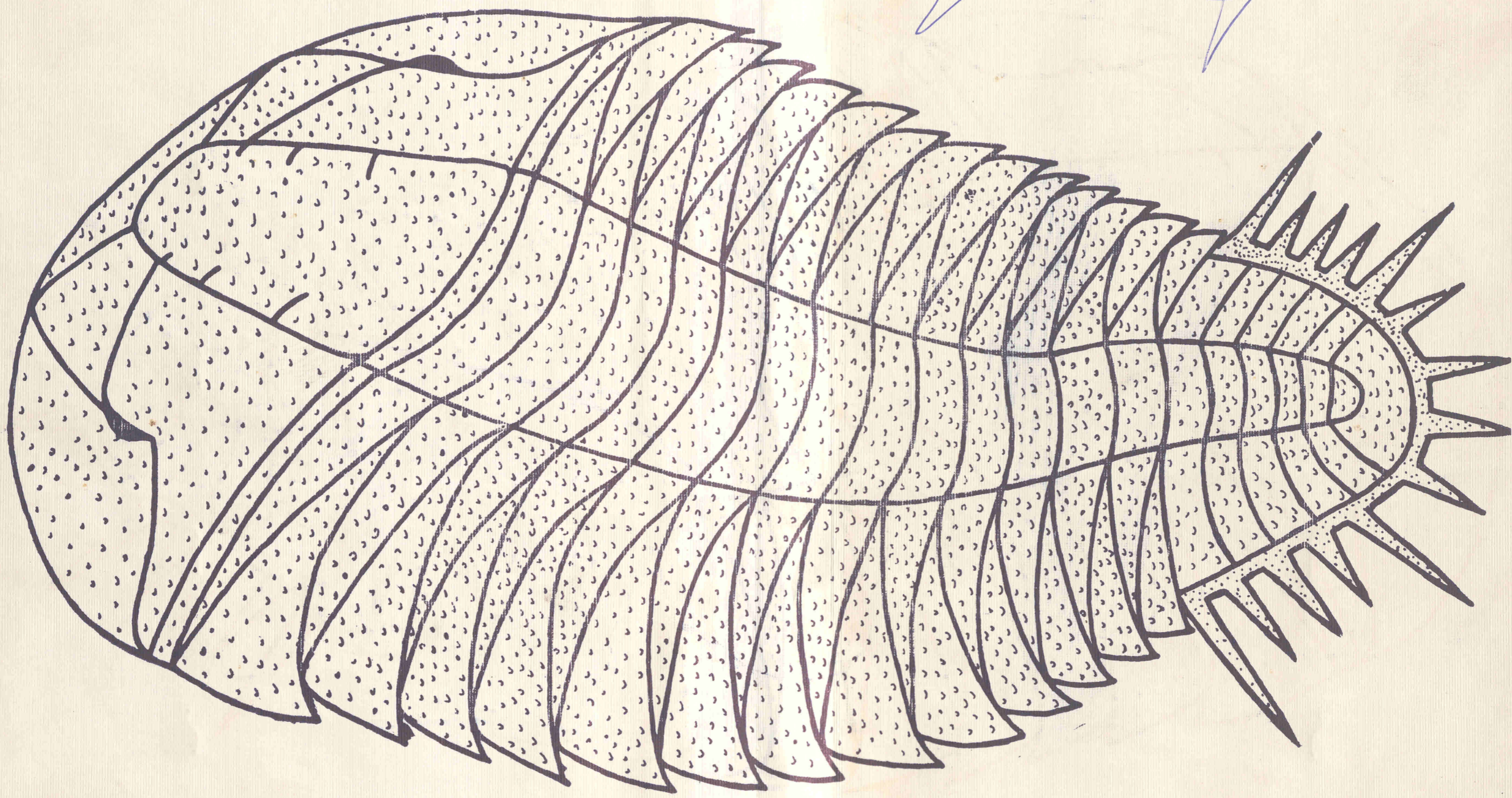
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SUBMITTED TO THE  
UNIVERSITY OF JAMMU

FACULTY OF SCIENCE  
POST GRADUATE DEPARTMENT OF GEOLOGY  
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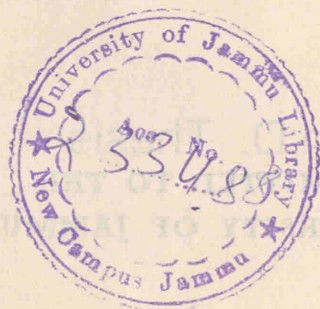
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# STRATIGRAPHIC GEOLOGY

LATE MIDDLE AND UPPER CAMBRIAN  
BIOSTRATIGRAPHY AND FAUNAL PROVINCES  
OF HIMALAYA

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1987

## CERTIFICATE

Certified that :

- i. the thesis entitled, " Late Middle and Upper Cambrian Biostratigraphy and faunal provinces of Himalaya " embodies the work of the candidate Sh. Alok Kishore;
- ii. the candidate worked under my supervision for the required period as per the university rules ;
- iii. the candidate has put in the attendance in the department during the period required under rules ;
- iv. the conduct of the candidate remained satisfactory during the period under research.

*[Handwritten signature]* 9.12.87

[ Prof. S.K. SHAH ]

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JAMMU, ( J & K State )

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P R E F A C E

"The race of man shall perish but the eyes  
Of trilobites eternal be in stone,  
And seem to stare about in mild surprise  
At changes greater than they have yet known".

- T.A. Conrad.

Fossils entombed in the stratigraphic rocks form a manuscript in stone and are the source of much of our knowledge of the past history. Study of the distribution of fossil animals and plants is potentially of great interest both to the biologist and the geologist. The former may learn more about how faunal and floral provinces of the present day came into being, and perceive interesting relationship with patterns of evolution and extinction. The latter will recognise much that can inform him on faunal provinces of past, which will help in deducing the ancient climates and land sea relationships.

Prior to the present studies not much work was done on provincialism and biogeography of Himalayan Cambrian. The limited nature of observations regarding the provincial setting of Himalayan Cambrian is understandable because only spot faunas from Kashmir, Spiti and Salt Range were listed and described at that time. So with the broad objective of having a comprehensive listing and description of fauna of Himalaya, a research project entitled, "Biostratigraphy of Cambro - Triassic Sequences of Tethys Himalaya"

with Prof. S.K. Shah as Principal Investigator was started in the University of Jammu. The present work constitute a part of this project.

In the course of present studies an attempt has been made to supplement the existing work and bring it at par with the modern concepts of stratigraphic classification, correlation and biostratigraphic zonation. Some unreported fossil taxa were also obtained which proved to be of considerable stratigraphic significance. An attempt has been made to determine a broad outline of the pattern of provincialism during Cambrian times and group different taxa on the basis of their sensitivity to various factors governing provincialism.

In the preparation of this thesis the author received help and support from many individuals and organizations. It is the proud privilege of the author to put on record the profound gratitude that he owes to Prof.S.K. Shah for initially suggesting the problem and then supervising and guiding the work at all stages with a considerable personal involvement.

The author is highly obliged to Dr.S.C.D.Sah, Prof. S.B. Bhatia and Shri H.M. Kapoor, for their comments and helpful discussions during the Group monitoring meeting of the project.

To other members of the teaching faculty of the Geology Department, University of Jammu, particularly to Prof. T.R. Sharma, the author is grateful for help and suggestions during the progress of this work.

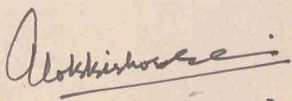
The author is thankful to his co-workers Dr. Sat Paul and Sh. Suraj Kumar Parcha for helpful discussions during field and laboratory studies, and all the research scholars of the department for their encouragement.

To Sh. Ashok Sahni my obligation is unbounded for his constant encouragement.

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Last, but not the least my deepest sense of gratitude is to my parents, brothers and sister for their constant encouragement and moral support.

  
[ ALOK KISHORE ]

A B S T R A C T

In the Himalaya, fossiliferous Cambrian rocks occur in both Tethys as well as in Lesser Himalayan belt, but taking into consideration the palaeogeographic aspect a clear distinction can be made between the sequences of the two regions. Whereas the Tethyan region has a nearly continuous sequence atleast throughout Early and Middle Cambrian, in the Lesser Himalaya the sequence is truncated and punctuated and

represents only a limited transgressive phase in Early Cambrian.

Three areas are especially important in the Tethyan region for the study of the Cambrian rocks. These are Kumaun, Spiti and Kashmir basins. As the present work is confined only to late Middle and Late Cambrian, the Kumaun basin, which has not yielded any fossils of undoubted Cambrian age except for a variety of ichnofossils, is outside the scope of the present work. However, Kashmir and Spiti regions have yielded a rich variety of trilobites which are being discussed presently.

Cambrian in Kashmir is represented by a massive sedimentary group comprising shale, sandstone and limestone known as Pohru Group, which extends into Ordovician as well. The rocks of this Group are exposed on the banks of Pohru river in Kupwara district of north western Kashmir. The Trahagam Formation of Pohru Group which represents late Middle and early Late Cambrian is well exposed in two sections viz .,

- (1) Magam section, comprising exposures seen from Batpura to north of Nilipura on the Magam side and also from Jagarpura water point to west of Nagri along the road to Gushi, and
- (2) Trahagam section, exposed near Trahagam spring and extending north-eastwards to Luderwan.

The fossiliferous Cambrian rocks in Spiti are exposed in the Parahio and Pin valley sections and constitute the Parahio Formation, which bear Middle and early Late Cambrian trilobites. While the Pin section exposed on the banks of river Pin from Muth to Shian and Baldor has yielded trilobites which are characteristic of middle part of Middle Cambrian and some ichnofossils of Early Cambrian age, the Parahio section on the left bank of river Parahio from Thango to Barachu has yielded a rich variety of trilobites ranging in age from middle part of Middle Cambrian to early Late Cambrian.

All the sections mentioned above, in both Kashmir and Spiti, were systematically measured by tape and compass method. A lithostratigraphic column of all these sections has been prepared and trilobite fauna collected from various levels. The fauna collected from Bolaspidella horizon and above in Kashmir and overlying the Ptychoparia horizon in Spiti has been systematically described and the ranges of individual taxa determined.

The systematic palaeontology contains the description of eighteen trilobite taxa out of which only one is an agnostid and the rest are polymerids. These include one new genus and four new species from Kashmir and one new genus and two new species from Spiti. Except for Olenus haimantensis from Spiti and Damesella

shergoldi, Blackwelderiodes monkei, Hundwarella kingi and various species of Bolaspidella, all other forms are being reported for the first time from the respective areas. Bathyriscus ? stoliczkai and Dicellosephalus ? interpres already reported from Spiti, are grouped together and given a generic shift as Hundwarella interpres.

On the basis of these studies faunal assemblages and assemblage zones for the late Middle and early Late Cambrian have been built which are represented by two zones in Kashmir and only one in Spiti. In all these sections the fauna ranges in age from late Middle Cambrian ( Menevian ) to early Late Cambrian (Maentwrogian ). The faunal assemblages of these two areas are as under :-

FAUNAL ASSEMBLAGE FROM LATE MIDDLE CAMBRIAN  
TO EARLY LATE CAMBRIAN FROM KASHMIR

- II      Damesella shergoldi Shah & Sudan, Blackwelderiodes monkei Húpe, Parablackwelderia sp., Dictyites sp., Haniwa transversa sp.nov., Blountia subangulata sp. nov., Blountia sp., Pedinocephalus kashmirensis sp. nov., Amurticephalus elongatus gen. et sp. nov., Walcottaspsis sp.
- I.      Bolaspidella himalayensis Shah & Sudan, B. magamensis Shah & Sudan, Bolaspidella sp., Hundwarella kingi Sudan, Cyclolorenzella sp., Diplagnostus sp.

FAUNAL ASSEMBLAGE FROM EARLY LATE  
CAMBRIAN OF SPITI

Olenus haimantensis Reed, Hundwarella rushtoni sp. nov.,  
H. interpres (Reed), Spitella barachuda gen. et sp.  
nov., ? Anomocarella sp., Tsinania sp.

These studies have helped to fix Middle - Late Cambrian boundary in both the areas. In Kashmir it lies between Bolaspidella Zone and Damesella Zone whereas in Spiti it is between Ptychoparia Zone and Olenus Zone. But Cambrian - Ordovician boundary cannot be fixed. In Kashmir, above the Damesella Zone (Maentwrogian) the next faunal unit after an enormous thickness of barren rocks has yielded Middle Ordovician brachiopods. The rocks are apparently conformable but probably represent a paraconformity. In Spiti after the Olenus Zone there is a distinct angular unconformity represented by reddish brown conglomerate. Here also the next faunal unit bears Middle Ordovician brachiopods.

The absence of middle and upper part of the Late Cambrian and Early Ordovician, exhibited by a paraconformity in Kashmir and an angular unconformity in Spiti, is possibly an epirogenic phase equivalent to Pan - African orogeny.

The comparisons of the fauna from Spiti and Kashmir between them and with that of China, Australia, Indochina, Iran, Kazakhstan,

Siberia, Great Britain, Norway, Sweden, North America and South America are also discussed. It has been found that different faunal elements compare favourably with those of China, Australia, Korea, Kazakhstan and Iran. However, the similarities are governed by various factors of provincialism.

By plotting the late Middle and Late Cambrian faunal data of Himalaya on palaeolatitudinal maps, an attempt has been made to determine a broad outline of the pattern of provincialism during these times. It has been found that the fauna fits in the provincial setting of Australo-Asian Superregion. Some of the shallow water elements fall within the palaeoclimatic zones and are not distributed outside them. It can be concluded that provincialism is of three types.

- (i) Geographical provincialism, governed by physical contiguity and easy dispersal.
- (ii) Palaeoecological provincialism, earmarking various magnafacies.
- (iii) Palaeoclimatic provincialism, governed by latitudinal position during Cambrian times.

In addition, a facies preference of some specific taxa is also noticeable especially since some of these are preserved only in specific rock types. This seems to be more a preservational factor than a provincial one.

Attempts have been made to group the various taxa on the basis of their sensitivity to various factors governing provincialism.

CHAPTER - I

I N T R O D U C T I O N

Scope and Method of Study

The Himalaya constitutes the mightiest mountain system in the world. It runs along a grand arc, convex to the south. This mountain range is the southern most and the youngest of the mountain ranges of Central Asia, and includes the highest elevation on the globe ( Mount Everest - 8848 Mts. ). Its longitudinal course is brought to an end by acute angled southward bend of the two mighty rivers, the Indus and Brahmaputra round two monolithic

peg like mountain peaks of Nanga Parbat and Namcha Barwa .

The evolution of this great mountain range has been attributed to the process of mountain building by Plate Tectonics . It represents a case of collision between two continental plates , the Indian and the Asian ( Dewey and Bird, 1970 ). The Indian plate had moved northward and a considerable part of the northern margin of Indian plate might have subducted down along the Indus Suture zone . The intervening sea , which must have been a mighty ocean , at least for a part of its life history , known as Tethys ( the name Tethys being given by Suess in 1893 ) is considered to have been consumed .

The nature , extent and the geological history of the Tethys ocean / linear sea has been variously interpreted ( Sylvester Bradley, 1967 ), but its existence almost throughout the Phanerozoic except for Neogene , has been universally admitted .

Stratigraphically and tectonically the Himalaya has been divided into outer Tertiary Zone , Lesser Himalaya , Central Crystalline axis , Higher Himalaya and Tibetan Himalaya . Higher Himalaya is also known as Tethys Himalaya and represents the remnant of Tethyan sediments . Southwards the Tethys sea seems to have transgressed upto Kumaun , Spiti and Kashmir . The

Tethyan sediments after their deposition were uplifted due to various tectonic movements during Himalayan Orogeny and thus the Tethyan sedimentary terrain got divided into different basins known as Kashmir basin, Spiti - Zaskar basin, Kumaun basin, Nepal basin and Bhutan basin, constituting the southerly peripheries of the main Tethys basin.

The Cambrian rocks in the Himalaya are known to occur in the Tethyan as well as Lesser Himalayan zone. In the Lesser Himalaya sparsely fossiliferous Cambrian rocks are found in Salt Range ( Pakistan ) and Tal sequence in Mussoorie and elsewhere, whereas in the Tethys Himalaya very richly fossiliferous ( particularly bearing trilobites ) Cambrian rocks are reported from Kashmir and Spiti areas. Of course, what must be Cambrian is also exposed in Kumaun-Nepal part of the Tethys belt but it is almost devoid of any body fossils. In all the areas, Late Cambrian is absent or highly restricted and only lower part of Late Cambrian is present in Kashmir and Spiti basins. The other areas, are, therefore, outside the scope of the present work.

#### KASHMIR :

Geographically, the Kashmir Valley is one of the largest of the linear strike valleys of the Himalaya. It is

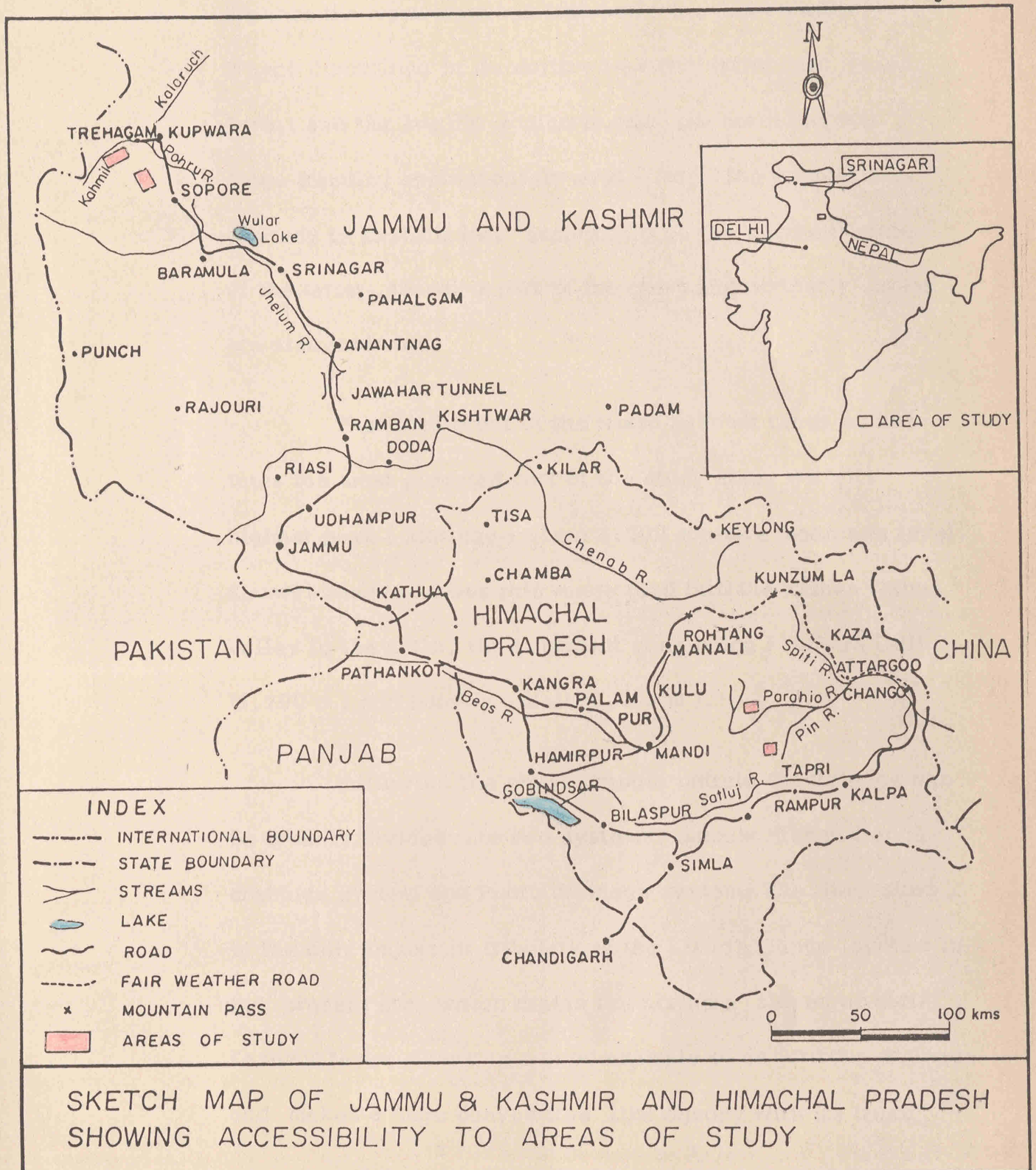
located in the north western part between the large Jhelum syntaxial bend to the west and a series of smaller structural embayments along Chenab and Ravi to the east. Nestled between the arcuate Great Himalayan range and the Pir Panjal range, the valley is an oval depression covered with lush green vegetation. River Jhelum draining the slopes of the ranges covers the central part of the depression with a blanket of sediments along the flood plains in the course of its leisurely meandering traverse.

The rich fossiliferous Cambrian rocks occur in the Kupwara district in north - western part of Kashmir valley. This part lies in the Survey of India Topographic sheets : 43 J/2, 43 J/3, 43 J/6 and 43 J/7 and is broadly restricted within the Latitude  $34^{\circ} 24'$  -  $34^{\circ} 38'$  N and Longitude  $74^{\circ} 15'$  -  $74^{\circ} 40'$  E.

The district headquarter, Kupwara lies within the area and is connected with Srinagar by a 85 km. long good, metalled road. The other important town is Hundwara, about 16 km. from Kupwara. On the whole the area is well connected with roads ( Fig. 1 ).

The northern limit of the Kashmir valley is bounded by

Fig. 1



SKETCH MAP OF JAMMU & KASHMIR AND HIMACHAL PRADESH SHOWING ACCESSIBILITY TO AREAS OF STUDY

the great Himalayan range for the most part but this range towards the west branches into two - the main northerly branch continuing in its north - westerly trend upto Nanga Parbat and the smaller southerly one, the north Kashmir range trending approximately east - west. The present area of study in Kashmir lies essentially on the southern slope of the latter, though a part of the crest and northerly slopes are also included.

The ridge crest of the North Kashmir range constitutes the most elevated part of the study area, with its highest peak ( Marinag ) about 3,600 m above mean sea level. Several passes across this range lead into the Kishen Ganga Valley to the north, the important ones being Pharkian Gali (3,200 m ) and Putakhan Gali (3,000 m ).

Following the physiographic pattern the drainage can be broadly divided into two systems, namely Kishen Ganga drainage system and Pohru drainage system. The Jume Gund is the only important tributary of the Kishen Ganga system in the present area which drains the northern slopes of north Kashmir range. Pohru is a good example of dendriform drainage and makes a huge banyan tree like canopy with its trunk

attached to Jhelum near Sopore. Its sizable tributaries such as Lolab, Kahmil, Talar and Mawar are the important sources for this system. Lolab stream has its source in Nagmarg and Bagalsar heights. Another affluent stream, namely Kalaruch joins it below Khumerial after receiving water from Rangtop, Nava Gali and Muthal heights. Near Kupwara, the Lolab takes a southerly bend and joins the Kahmil stream from the west and the river thereafter is known as Pohru. The Kahmil stream drains the western part of north Kashmir range and also a part of the western Shamshabri range.

The valley of Kashmir on the whole with its adjoining north - western and south - eastern high land areas has a fine spring season extending from March to middle of May. The summer is less rainy than the spring and quite warm. The autumn marks a transition from the warm subtropical summer to temperate winter. The winter months from December to February are very cold with minimum subzero temperatures and invariably snowy.

The natural vegetation of Kashmir valley and its adjoining mountainous regions may be broadly divided into two typological divisions, namely forest and grasslands, although there also occur some intermediary types which appear as undergrowth in

forests and uncultivated tracts along the river banks.

#### SPITI :

This region is in the northern part of India and lies in the north eastern part of the Himachal Pradesh. It touches the boundary of Tibet in the east and Ladakh region of the J & K State in the north. It is sparsely inhabited, the population being only along the banks of river Spiti and its tributaries.

The area of study lies in the southern part of the Lahaul and Spiti district of Himachal Pradesh. It is broadly restricted within Longitudes  $77^{\circ} 55' 30'' - 77^{\circ} 56' 10''$  E and Latitudes  $32^{\circ} 1' 45'' - 32^{\circ} 2' 35''$  N and is included in the Survey of India Topographic Sheet number 52 H/16.

The main town in this area is Kaza which is approachable by two roads. One of these roads is from Manali, crossing Rohtang and Kunzam La passes. This road from Gramphoo to Kaza is unmetalled and remains open from Middle of July to late October. The other road is along rivers Satluj and Spiti from Rampur to Kaza, crossing Kinnuar district. This is a nice road and remains open almost throughout the year. From Attargoo, a small village about 15 km. from Kaza, on

Kaza- Rampur road, the area of study ( Thango ) is about 40 km. by foot along a rough mule track( Fig. 1 ).

Spiti region, is a valley along river Spiti which is bounded by a complex net work of nude, bleak, barren and mighty ranges of Great Himalaya, being inhospitable, inaccessible and devoid of vegetation. The area is surrounded by the Zanskar range in the north west, which even extends to a smaller part of this valley and by Tibetan range in the east. The main valley is carved by river Spiti and its important tributaries viz., Pin and Parahio (Barachu ). These valleys support habitation as well as the meagre cultivation and vegetation. The study area lies in Pin and Parahio ( Barachu ) valleys.

In the area under study the lowest point is at Thango (3,050 metres ) and the highest point is an unnamed hill top (5,250 metres ) just above Maopo. The area has a steep and rugged topography and forms a part of Spiti drainage system. Spiti river originates from the northern mountains of Kunzam La pass ( north - west ) and has a general south east flow. The Spiti river is the largest tributary of river Satluj, which has a westerly flow. It joins Satluj near Puh. The Parahio (locally called Barachu ) and Pin rivers are the main tributaries of the Spiti river. Parahio flows in an easterly direction and Pin in a

northerly direction till they meet each other near Sagnam from where they have a general north east flow and meet river Spiti near Lingti. Generally these two streams cut across the regional strike which is NW - SE along which the river Spiti flows.

The climate is one of the fierce extremes, ranging from the burning heat like some of the desert tracts of the Panjab plains in the day in summer to several degrees below freezing points at night in winter. Because of these unfavourable climatic conditions, vegetation is scanty. However, some meagre cultivation is attempted in the valleys along river Spiti and its tributaries.

#### SCOPE AND METHOD OF STUDY :

Cambrian fauna is reported from Parahio valley, Spiti and Kupwara district of Kashmir since the early part of the present century. The studies in these areas were conducted at times when the stratigraphic concept were not well understood. While the bulk of the fauna belongs to middle part of Middle Cambrian, very little material is available from the late Middle and Late Cambrian. The only early reports of definite Late Cambrian fossils are available from Spiti ( Reed, 1910 ) and Kashmir (Reed, 1934). Of these the Late Cambrian trilobite forms reported from the latter area, mainly Chuangia and Saukia have been found to be as

incorrect identifications ( Shah, 1982 ). Recently, however, some late Middle and early Late Cambrian elements have been reported from Kashmir ( Shah, 1982 ; Shah and Sudan, 1983; Jell, 1986 ) but the Late Cambrian forms refer especially to its lowermost part and do not go beyond the corresponding Olenus Zone of Scandinavia. The same situation exists in Spiti where the youngest Late Cambrian horizon belongs to Olenus Zone. The zonation of late Middle and Late Cambrian in Himalaya is, therefore, far from satisfactory.

Moreover, the greater knowledge of biostratigraphy has brought out the finer details of intra- System boundaries throughout the world and, therefore, a more systematic work is necessary in the Himalaya as well.

With this as broad objective, in the present work an attempt was made to undertake the study on the following lines :-

- i) Several Cambrian sections in the Kupwara district of Kashmir and Pin and Parahio valleys of Spiti were chosen. These were systematically measured by tape and compass method in undulating terrains or pacing in relatively flat terrains.
- ii) A lithostratigraphic column for these sections was prepared on the basis of above measurements.

- iii) The different faunal zones in these sections were located and superimposed on the lithostratigraphic column.
- iv) Fauna was collected from all the horizons of various sections and plotted in the column.

A detailed study of all the faunal assemblages collected from these sections is beyond the scope of the present work. The faunas collected from Bolaspidella horizon ( reported earlier by Shah & Sudan, 1982 ) and above in Kashmir and above Ptychoparia horizon in Spiti were taken for detailed studies as this part of the sequence represents late Middle Cambrian and ages younger to that. The fauna thus selected was identified and described systematically and only those forms are described in the present work which either require the updating of the nomenclature or are new.

An attempt was made to work out the biogeography and biofacies relationship of the fauna, which will throw light on provincialism, if any.

All this data has been collected and superimposed on the stratigraphic columns and attempts have been made to interpret it for the following purposes.

- a) Compare the faunal assemblages with the standard

sections of the world for correlation of the different zones.

- b) Demarcate any period of potential non-deposition or local diastems and estimate their span.
- c) Fix the precise intra-System boundary and biostratigraphic zonation for late Middle and Late Cambrian of Himalaya, demarcating the cosmopolitan and local fauna on the one hand and facies fauna and transfacies fauna on the other.
- d) Compare the assemblage with the known biofacies realms and to draw palaeoecological conclusions.
- e) To determine the basis of provincialism, i.e., geographical, climatic, environmental.
- f) To test the hypotheses of provincialism on the geographical contiguity as determined from palaeomagnetic data.

The studies are based only on the megafossils. The biostratigraphic appraisal is, therefore, purely based on

trilobites which, in any case, are highly distinctive for Cambrian zonation. A superimposition of the assemblages of microblota on these zones is, therefore, outside the scope of the present work.

CHAPTER - II  
REVIEW OF THE PREVIOUS LITERATURE

The Tethyan Himalayan belt contains some of the best known fossiliferous sequences of the world. The geological studies in this belt started from early nineteenth century but systematic studies were only undertaken towards the later part of that century.

The earliest reference to the geology of this belt is from

Strachey ( 1857 ) who gave the name " Azoic " to the most southerly " band ", which constitutes the oldest known sedimentary system in the region. Godwin Austin ( 1861 , 1864 , 1866 ) while studying some aspects of the geology of Kashmir gave a brief account of Carboniferous rocks of Kashmir valley. An interesting study of a regional nature was the one undertaken by Stoliczka ( 1866 ), who traversed through Spiti, Rupshu into Ladakh and Karakorum and gave the first geological classification of the rocks of Spiti -Ladakh area. Drew ( 1875 ) gave an account of the physical features and geography of Kashmir.

Lydekker ( 1878, 1883 ) described a number of sections in Kashmir and introduced a workable stratigraphic classification. He divided the stratified formations into three broad divisions, namely, the "Panjal System ", comprising of the entire Palaeozoic and a part of Mesozoic, the remaining Mesozoic in the "Zanskar System " and the " Tertiary System ".

Oldham ( 1888 ) attempted to correlate the beds of Spiti with the pre- Tertiary formation of the outer Himalaya.

Griesbach ( 1891 ) conducted geological studies in the Spiti area and grouped the oldest sedimentary rocks into one System and named it as "Haimanta System " (including Bhabeh Seres of Stoliczka ). He divided Haimanta into three parts as : -

- |                 |   |
|-----------------|---|
| HAIMANTA SYSTEM | (c) Upper Haimanta : - Quartz, shale and slate.   |
|                 | (b) Middle Haimanta :- Shale and silky phyllite with great thickness of quartzite.      |
|                 | (a) Lower Haimanta : - Quartzite generally purple with great thickness of conglomerate. |

The most exhaustive and in many respects the pioneering work in Spiti is by Hayden ( 1904 ), which has formed the basis for all the subsequent work in this area. According to him only Upper and Middle Haimanta of Griesbach can be readily recognised in all the older Palaeozoic sections in Spiti and Bashahr, but the Lower Haimanta characterised by the presence of conglomerate has not been found. To the Upper part of Haimanta of Griesbach he gave the name " Parahio Series ", and assigned it Middle and Late Cambrian age.

The most complete section of Parahio " Series ", was

seen by him on the bank of Parahio river above Maopo, which is given below :-

	<u>Thickness</u> <u>(in feet)</u>
19. Conglomerate	-
18. Quartzite and siliceous shales	about 50
17. Grey dolomite, weathering brownish red	" 20
16. Flaggy sandstone, quartzite and siliceous slates	" 40
15. Grey dolomite weathering brownish red	" 30
14. Siliceous slates with grey quartzite band and thin beds pink dolomite slates chiefly grey and green.	" 250
13. Dark siliceous slates with trilobites	" 10
12. Siliceous slates and flaggy quartzites	" 30
11. Siliceous and argillaceous slates with trilobites	" 6
10. Grey slaty quartzite, capped by dolomite	" 50
9. Slate siliceous above and argillaceous below with trilobites	" 30
8. Dark grey quartzite	" 60
7. Pink shaly dolomitic limestone with trilobites	" 12
6. Calcareous quartzite with <u>Lingulella</u> and trilobites, underlain by narrow band of fossiliferous limestone and argillaceous slates with many trilobites	" 10

5.	Grey micaceous quartzite, with thin bands of mica schist	About	150
4.	Slates alternating with narrow bands of grey limestone with <u>Lingulella</u> and trilobites.	"	10
3.	Slate chiefly siliceous and quartzite	"	150
2.	Dark slate with trilobites	"	30
1.	Red and green slaty quartzite with <u>Lingulella</u> and trilobites	"	250

Hayden (op. cit.) concluded that considering the relative thickness of " Parahio Series " and the lower subdivisions and comparing these with the thickness of Cambrian System in other Parts of the world, it would seem quite justifiable to include the whole sequence, which is a perfectly continuous one, in the Cambrian System, and thus dispense in Spiti with the provisional terms " Bhabeh Series " and " Haimanta ".

Middlemiss ( 1909, 1910, 1911 ) gave a detailed account of the marine sedimentary system of Kashmir and in a way established the base for a sound stratigraphic classification. He also worked out the stratigraphy of the south - eastern regions of Kashmir from Silurian to Trias and collected some Silurian fossils from Naubug Valley, Harptnar Valley and near Margan Pass and Anantnag district.

Reed ( 1910 ) identified and described the fauna collected by Hayden from Spiti.

Wadia ( 1928, 1931, 1934 ) considerably improved the stratigraphic classification of Middlemiss in addition to extending it further west in Kashmir. He introduced several names notably " Salkhala Series " and " Dogra Slates " to demarcate the unfossiliferous and mainly Precambrian formations of Kashmir. One of his major contributions was the record of fossiliferous Cambrian from north western Kashmir.

Broadly Wadia's stratigraphic classification for western Kashmir can be summarized as follows :-

Upper Trias		Upper Triassic Limestone of Gurias
Muschelkalk	PANJAL TRAP	Intercalations of Middle Triassic limestone trap
Lower Trias		Imbersilwar Limestone trap Inter-bedded Infra - Trias and Lower Trias of Uri mountains
Permian	AGGLOMERATIC SLATE	Plant beds Khunmu Plant Trap flow Plant beds of Nagmarg
Upper Carboniferous		Agglomeratic slate and Apharwat and Bren plant beds

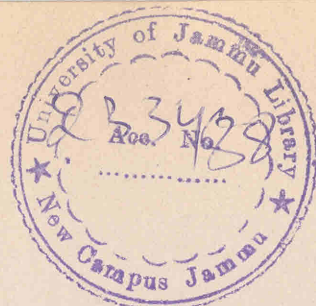
Middle Carboniferous -	
Lower Carboniferous	Tanwal Series
Devonian	Muth Quartzite
Silurian	? Silurian of Shamsabri
Ordovician	Ordovician beds of Marhaum
Cambrian	Upper fossiliferous clays, shales and limestone bearing trilobites
	Lower annelid slates, sandstone and quartzite
	Dogra Slates
Precambrian	Salkhala Series

Wadia ( 1934 ) was the first geologist to record the Cambrian trilobites from Kashmir.

The Cambrian and Ordovician fauna collected by Wadia was systematically described by Reed ( 1934 ) , who found all the species to be new and concluded that the Cambrian fauna of Kashmir was of an endemic nature .

Kobayashi (1934) independently collected Cambrian fauna from the same area and described a few forms.

In recent years considerable work has been undertaken on the various aspects of the stratigraphy and palaeontology of



both Kashmir and Spiti regions. To list all of them here is not possible. However, the contributions relevant to the present work are broadly summarized below :-

Wakhaloo and Shah ( 1965 ) discussed the palaeo-geographic significance of Cambrian fauna of Kashmir, while ruling out the earlier concept that Kashmir, Spiti and Salt Range represent different faunal provinces, they concluded that during Cambrian times the entire Himalayan region was covered by the same sea and the variation in fauna of all the three regions is because of environmental factors.

Shah ( 1968 ) gave a lithostratigraphic classification for the Lower Palaeozoic sedimentary rocks in Pohru valley of north - western Kashmir and grouped it into a single group named as " Pohru Group ". He further subdivided the "Pohru Group " into six formations ranging from Early Cambrian to Silurian. His lithostratigraphic classification is as under :-

Lithological Units :

Marhaum Formation  
Trahagam Formation  
Nutnus Formation  
Sagipura Formation

Lolab Formation

Marinag Formation

The palaeoecology of the Lower Palaeozoic sequence of Kashmir has been discussed by Shah ( 1971 ). He also gave the biostratigraphic classification based on the faunal distribution.

Shah ( 1973 ), for the first time recorded the complete exoskeletons of conocoryphid trilobites from Cambrian sequences of Hundwara region of Kashmir, including several new species.

Gupta and Suneja ( 1974 ) discussed the Cambrian sequences in the Tethyan region and they opined that the Indian region remained under the influence of the western arm of Australo - Asian marine province throughout the Cambrian period and was in contact with the Pacific province on one hand and Atlantic on the other during the Middle Cambrian period.

Jell ( 1974 ) while discussing Middle Cambrian provincialism has included Himalaya along with Siberia, Australia, Antarctica, China and other parts of Asia into Tollchuticook province. He suggested that the Redlichia, a characteristic Early Cambrian trilobite form from this region

cannot be used to indicate a faunal province as has been done in the past and he concluded that biogeographic component of the faunal dissimilarity overrides the biofacies component.

Gupta and Kumar ( 1975 ) has described the regional geology of Lahaul and Ladakh.

Goel and Nair ( 1977 ) has classified the Lower Palaeozoic sequence of Pin - Parahio valley in Spiti.

Gupta ( 1977 ) while discussing Palaeozoic biostratigraphy and palaeogeography of the Himalaya stated that the new fossil finds have helped to resolve some of the palaeogeographic anomalies existing due to the presumed absence of certain groups of organisms from the Himalaya .

Gupta and Suneja ( 1977 ) described new species of trilobite genus Iranoleesia from the Cambrian sequence of Hundwara region of Kashmir.

Srikantia ( 1977 ) suggested that Himalaya has its unique pattern of sedimentary cycles and their relationship with orogenic episodes, which may differ from the pattern of other mountain belts.

Shah ( 1978 ) gave a detailed account of the facies

distribution in the Palaeozoic sequence of Kashmir within the tectonic setting of Himalaya and made a comparative study of the Palaeozoic facies within the Kashmir basin.

Srikantia et al. ( 1978 ) gave a detailed stratigraphic classification of rocks in Lahaul and Spiti district and in Zaskar area of Ladakh.

Suneja ( 1978 ) discussed the Palaeozoic stratigraphy of north - western Kashmir and gave a checklist of the Cambrian fossils recorded from the north - western Kashmir by earlier workers.

Srikantia ( 1981 ) discussed about the lithostratigraphy, sedimentation and structure of Proterozoic- Phanerozoic formations of Spiti basin and concluded that the Haimanta represents a cycle of geosynclinal sedimentation whereas Takche Formation represents a shallow marine and Muth Formation as beach type environments.

Fuchs ( 1982 ) discussed in detail about the geology of Pin Valley in Spiti.

Ranga Rao et al. ( 1982 ) prepared, measured lithological column for various sections viz., Parahio, Pin , Kunzam La, Takche

etc. in Spiti and superimposed biostratigraphic data on these columns. They also reported the Cambrian fossils from Kunzam La section.

Shah ( 1982 ) gave the biostratigraphic classification of Kashmir dividing it into assemblage zones on the basis of trilobites and trace fossils. He also discussed the boundary problems of this system in the Himalayan context.

New species of Bolaspidella from Magam region of Kupwara district of Kashmir were described by Shah and Sudan (1982). It was the first report of this genus from Asia.

Shah and Sudan ( 1983 a, 1984 ) described the Cambrian trace fossils from Kashmir and discussed their stratigraphic significance.

Shah and Sudan ( 1983b, 1987a ) described, for the first time, genus Damesella from Kashmir and discussed its stratigraphic significance.

Kumar et al. ( 1984 ) studied the Precambrian - Cambrian boundary problem in Kashmir and Spiti. They concluded that because the yield of microbiota is poor and the trace fossils are late Early Cambrian the boundary cannot be precisely fixed in these two areas.

Garzanti et al. ( 1986 ) stated that Tethys Himalaya provides evidence of an orogenic episode close to Cambro-Ordovician boundary and the succession in this belt shows an over all transgressive trend.

Jell ( 1986 ) described a trilobite faunule from Trahagam area of north western Kashmir. While comparing these forms with Chinese and Australian forms, he assigned them to early Late Cambrian. There is no doubt regarding the stratigraphic age but his claim that this faunule is the first unequivocal report of Late Cambrian sediments in Kashmir is untenable. Because, in several recent publications which include those on biostratigraphy and systematic palaeontology of Kashmir Cambrian, the occurrence of early Late Cambrian in Kashmir has clearly been established ( Shah, 1982 ; Shah & Sudan, 1983; 1984 ; 1987 ). Secondly, his questioning the assignment of some late Middle Cambrian form to Bolaspidella by Shah and Sudan ( 1982 ), is not the first time that doubts have been expressed about the reference of Kashmir material to that genus ( see Kumar, 1983 ; Shah, 1983 ) but the matter has been put to rest after the publication of quantitative data on the Kashmir forms ( Shah et al., 1985 ).

Shah and Sudan ( 1987b ) described several species of agnostids from the Cambrian and discussed their importance in the biostratigraphic zonation of Kashmir Cambrian .

CHAPTER - III  
CAMBRIAN SEQUENCES IN HIMALAYA

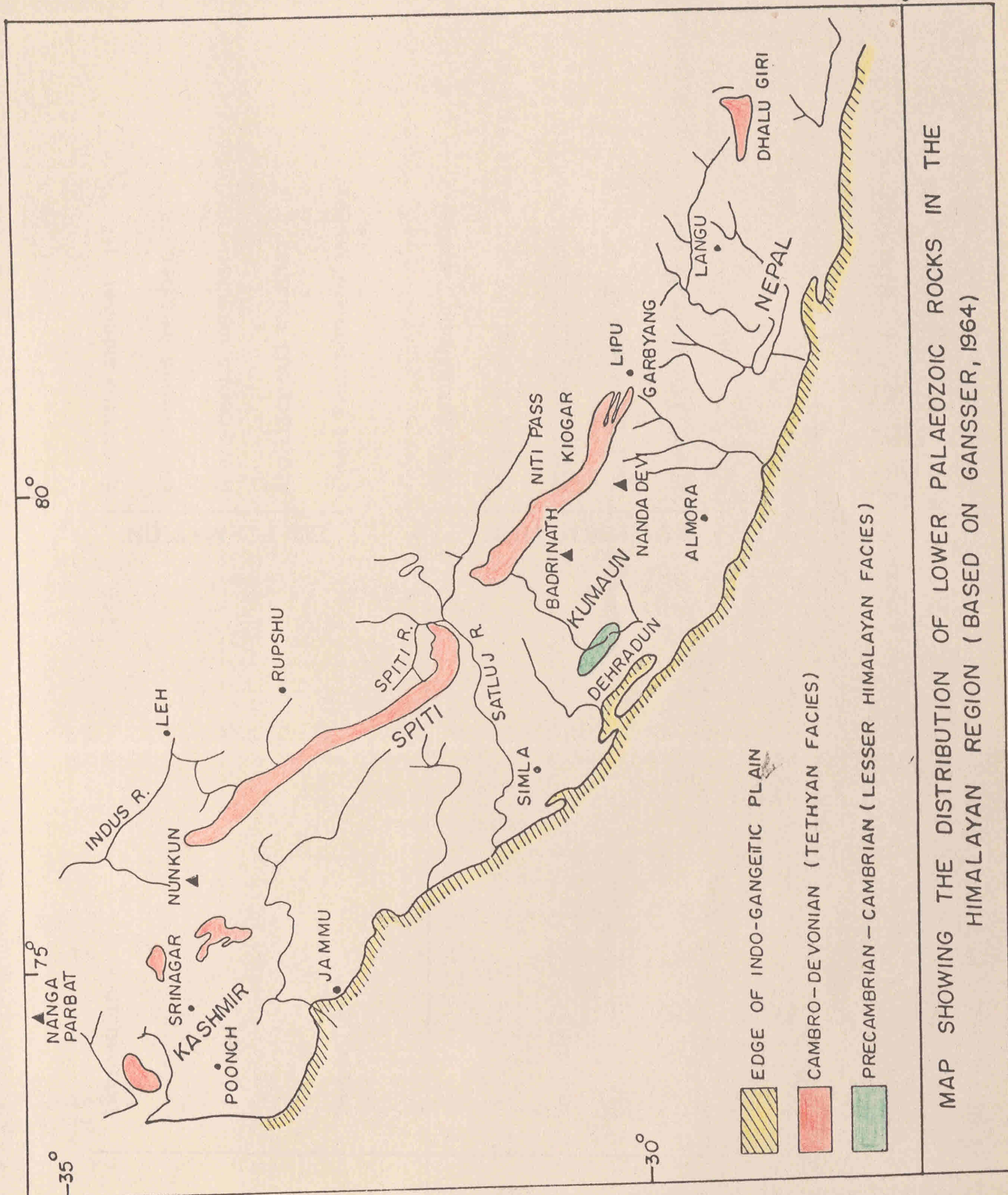
Fossiliferous Cambrian rocks occur in Tethys as well as Lesser Himalayan belt but a clear distinction can be made between the rocks of the two regions taking into consideration the palaeogeographic aspect. As is well known, the widespread distribution of earliest Cambrian in many parts of the world was a result of Varangian glaciation which could be dated to 600 m.y. After these glaciers melted there was a world wide transgression. As a result of this transgression several

parts of the land area got submerged or inundated near the coastal regions and, therefore, the coastal facies of Cambrian are widely distributed especially during the lowermost part of Cambrian and it is this kind of facies which occurs in the Lesser Himalaya during Cambrian times. Fig. 2 shows the distribution of Lower Palaeozoic rocks in the Himalayan region.

In the Lesser Himalaya the Cambrian sequences have been reported from Mussoorie in India and Salt Range in Pakistan.

In Mussoorie the sequence has yielded a variety of archaeocyathids, hyolithids, acritarchs and some algal forms, but the discovery of these forms of Early Cambrian age had created a big controversy because several workers on the basis of these forms tried to fix Precambrian - Cambrian boundary at different positions ( Azmi, 1983 ; Azmi and Pancholi, 1983 ; Singh, 1981; Singh and Rai, 1983). But this has now been almost resolved and the Precambrian - Cambrian boundary is fixed below the chert phosphorite member ( Singh and Rai, 1984 ) in the upper part of Krol.

Fig. 2



MAP SHOWING THE DISTRIBUTION OF LOWER PALAEOZOIC ROCKS IN THE HIMALAYAN REGION (BASED ON GANSSER, 1964)

	CAMBRIAN	Atdabanian	TAL FORMATION	Quartzite member Calcareous member Arenaceous member Argillaceous member Chert Phosphorite member
	PRECAMBRIAN	Vendian	KROL FORMATION	Grey Limestone member Cherty Limestone and Shale member Bluish grey Limestone member Red Shale member Grey Limestone member

In the Salt Range the succession is as follows :-

	Salt pseudomorph Shale
early Middle Cambrian	Magnesian Sandstone
Early Cambrian	Neobolus Shale
	Purple Sandstone
	Saline " Series "

As can be seen from above, the sequence in both these areas is not complete but is truncated and punctuated and it represents only a part of the Cambrian. In Mussoorie, Tal Formation which is Cambrian, represents Tommotian and extends a little up into Atdabanian stage of Early Cambrian whereas Middle and Late Cambrian are absent here. A few months ago redlichid fauna characteristic of late Early Cambrian, is known to have been reported from lower part of Phulchatti Quartzite Member, exposed in Nigalidhar Syncline, Himachal Pradesh ( Kumar *et al.*, 1987 ) and Garhwal Syncline above Rishikesh ( D.K. Bhatt , personal communication ). In the Salt Range the sequence does go a little higher up into Middle Cambrian, which is represented by Magnesian Sandstone containing ptychoparids whereas the underlying Neobolus Shale is Early Cambrian. Here also the late Middle and Late Cambrian is absent. So the Cambrian sequence of Tethys belt which is nearly complete, passing

from Precambrian into Early Cambrian, Middle and early part of the Late Cambrian cannot be equated or treated at par with the sequence of Lesser Himalayan belt, the latter being just a small remnant of a transgressive sequence.

In the Tethyan belt, two regions are especially significant for the occurrence of Cambrian rocks. These include Kashmir basin higher up in the northwestern part of Himalaya and Spiti - Zaskar basin which is lying enéchelon with the Kashmir basin. Both of these areas are very rich in Cambrian faunas, especially trilobites. In the third region i.e., Kumaun - Nepal part of the basin, the Cambrian ( Garbyang ) is nearly unfossiliferous except for some unidentifiable fragmentary trilobites and, therefore the biostratigraphy is rather poorly defined. Though a variety of trace fossils have been reported, they represent only Early Cambrian and secondly they are not of much significance for correlation purposes. Therefore, Kashmir and Spiti successions happen to be by far the best Cambrian sequences in the Indian subcontinent. Each of these two successions are discussed below :-

KASHMIR :

The Cambrian System in Kashmir comprises part of a nearly continuous sequence ranging in age from Pre - cambrian to Triassic . The sequence is exposed in a large synclinorium, the southern limits of which are bounded by a thrust of considerable extension, the Panjal Thrust . Towards the northern and north - eastern part, the basin gets truncated by a major crustal feature, the counter - thrust or Indus Suture . Between these two important structures, the Kashmir basin along with its crystalline basement is exposed. The basement is composed of a thick succession of metasediments ( Salkhala Group ) which occasionally show a high grade of metamorphism. These rocks are exposed along the basement high linear belt in the north, along the Kishen Ganga valley, as also along the south and south - eastern periphery.

The best exposures of Cambrian are seen in Anantnag in southeast and Kupwara in the northwest of Kashmir but it is only in the latter area that the rocks are very rich in fossils. Probable Cambrian rocks, are also exposed in Sind Valley but they are devoid of fossils whereas in the

Pir Panjal Range only Ordovician and Silurian are fossiliferous but the underlying possible Cambrian rocks are unfossiliferous.

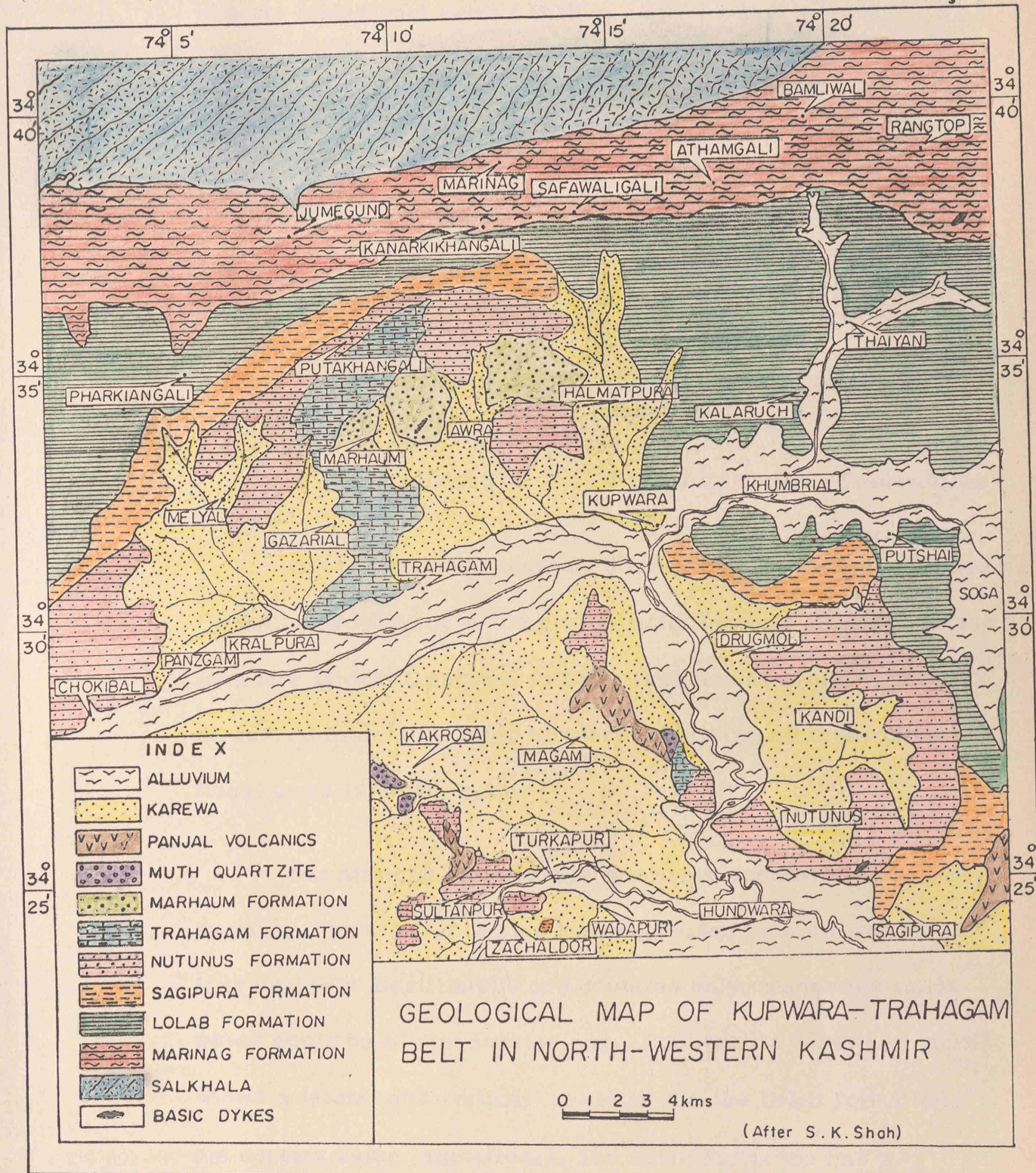
In the Liddar Valley of Anantnag district of eastern Kashmir the Cambro - Silurian rocks are exposed in the central part of a north westerly plunging Kotsu anticline, flanked on its two sides by younger formations, Devonian and Carboniferous. Similar type of rocks are exposed in Basmai anticline of Kolahai - Pahalgam region. In both the anticlines, the entire Cambrian and Early Ordovician sequence is generally unfossiliferous, but from Middle Ordovician onwards the sequence is fossiliferous. In recent years, Middle Cambrian trilobites have been reported from this sequence at Karihul near Hapatnar ( Kumar and Singh, 1983 ).

Fossiliferous Cambrian rocks are known from the Pohru Valley ( Kupwara district ) in the northwestern part of Kashmir basin, where they are richly fossiliferous and overlain conformably by Ordovician sediments. Here the rocks are exposed as a part of the folded sequence involving Cambrian, Ordovician and Silurian over which are resting the Panjal Volcanics of Permo - Carboniferous age with a distinct

angular unconformity ( Wadia, 1934 ; Shah, 1968 ). Bulk of the outcrop width of the Lower Palaeozoic comprises the Cambrian. Cambrian passes downward into the Precambrian and the entire sequence rests on a schistose basement (Salkhala Formation ), the contact being usually a faulted one ( Fig. 3 ).

To the east of Shamsabri syncline Late Precambrian to Lower Palaeozoic rocks are only exposed in a folded belt extending from Chowkibal to Nagmarg in the north and Dardahaj to Harwan in south. This constitutes the bulk of the drainage catchment area of the Pohru river which along with its tributaries dissect across the sequence. This sequence was named as Pohru Group ( Shah, 1968 ) . The Pohru Group being severely folded does not reveal any section which exposes the complete sequence and the stratigraphy is to be pieced together from several sections. An almost persistent Quaternary cover especially along the valley sections makes the task none too easy. Moreover, the lithostratigraphy shows a considerable lateral variation and almost all the formational units have both a vertical and lateral passage. As a result the stratigraphic succession is variable lithological and formational boundaries are not distinct.

Fig. 3



The Pohru Group has been lithostratigraphically divided into six formational units ( Shah op. cit. ) which are as follows :-

	<u>FORMATION</u>	<u>AGE</u>
POHRU GROUP	Marhaum	Silurian-Middle Ordovician
	Trahagam	Early Ordovician- late Middle Cambrian
	Nutunus	Middle Cambrian
	Sagipura - Lolab	early Middle Cambrian -Early Cambrian
	Marinag	? Early Cambrian - Precambrian

Out of the above mentioned formational units only Trahagam Formation is relevant to the present work because it ranges in age from late Middle Cambrian to Early Ordovician. While it is being discussed in detail a brief summary describing all other formational units is given below :-

The Marinag Formation is relatively deformed, compared to younger units, and is also metamorphosed to some extent. It is scarcely fossiliferous and contains only meandering trails which could be of Precambrian age. Towards its upper part it shows a lateral and vertical passage into the Lolab Formation, the contact being gradational. The Lolab Formation has a

considerable outcrop width in the Lolab valley, where it is repeated due to tight and often isoclinal folding. In the absence of well marked faunal horizons in the lower part, the folding and inversion can be resolved only by sedimentary structures and schistosity relationship. The Sagipura Formation is a facies variant of the upper part of Lolab Formation into which it shows a lateral and vertical passage. It consists of brown sandy shale, interbedded with buff coloured quartzite and differs from the underlying Lolab Formation, mainly in the nature and colour of shales. The outcrops of this Formation are not persistent in the area. It does not extend towards the northern part of the Cambrian basin where Lolab Formation has a direct and conformable passage into the overlying Nutunus Formation. The Nutunus Formation is exposed along the northern limb of Marhaum syncline from Riddi through Pharkian upto Putakhan Gali and to the west upto Halmatpura, but along the southern limb the Formation is covered by Kahmil river alluvium. This Formation has a maximum development, however, in the Kandi syncline where it occupies a maximum outcrop width along both the limbs and along its culmination. This Formation consists of greenish to bluish-green and brown thin bedded

shale interbedded with mudstone and micaceous sandstone with occasional graded bedded and ripple marked surfaces. The greenish and brown bands of shale commonly bear fossils in a good state of preservation. At places sandstone bands also yield ichnofossils. The quartzitic component which is universally present in the underlying, Lolab and Sagipura Formation is absent in the Nutunus Formation.

The Trahagam Formation represents the topmost formational unit of Cambrian i.e., late Middle and early Late Cambrian. Therefore, all the aspects of the present studies in Kashmir are based on the fauna collected from this Formation. It differs from all the underlying formational units in the presence of carbonate rocks interbedded with shale. This Formation is well developed in two sections viz., Magam section and Trahagam section. In the Magam section the exposures are seen from Batpura to north of Nilipur in Magam side and also from Jagarpura water point to west of Nagri along the road to Gushi where it is overlain by a 30 metre thick band of buff coloured quartzite, probably representing the Muth Quartzite. This section bears well marked fossil horizons very rich in trilobite fauna. The sequence of rocks in this section along with their thickness is as under :-

L I T H O L O G Y	T H I C K N E S S ( in metres )
12. Buff coloured quartzite	30
11. Thin band of sandstone	2
10. Green shale with interclated thin bands of purple shale	48
9. Arenaceous shale with unidentifiable fragmentary cheeks of trilobites	8
8. Brown arenaceous shale alternating with thin bands of green shale having a rich trilobite fauna	26
7. Green shale	8
6. Green shale bearing trilobite fauna	29
5. Arenaceous shale	9
4. Green shale	13
3. Arenaceous brown shale bearing fragmentary remains of trilobite fauna	22
2. Compact green shale bearing trilobites	19
1. Arenaceous shale with fragmentary remains of organisms	3

The fauna is collected from horizon nos. 2, 3, 6, 8.

Horizon 2 has yielded several species of Bolaspidella which have been described by Shah & Sudan (1982). So their systematic palaeontology is not taken in the present work. Horizon no. 3 contains a variety of very poorly preserved agnostids from which

only one form viz., Diplagnostus is identifiable. The trilobites Blountia, Cyclolorenzella and Hundwarella occur in the horizon no. 6. From horizon 8 a rich population of trilobites including Damesella, Pedinocephalus, Amurticephalus, Walcottaspis, Haniwa, Dictyites and Blountia has been found.

In the Trahagam section the outcrops of this Formation exposed near the Trahagam spring consist of greyish - blue massive limestone interbedded with greenish shale. After a partial alluvial cover, the sequence is, however, continuously exposed north - eastwards to Luderwan and then to Marhaum. The outcrops exposed near Trahagam spring have yielded some deformed trilobite fossils of early Late Cambrian age. The extraction of the fossils becomes somewhat difficult as the schistosity remains oblique to the bedding plane. The outcrops from Luderwan to Marhaum though having a massive thickness of bluish - green limestone alternating with green shales is devoid of any fossils. The sequence of the Formation as exposed in this section is as under :-

Lithology	Thickness (in metres)
7. Buff coloured limestone alternating with green shale	34
6. Green shale	8
5. Bluish - green limestone	10
4. Unfossiliferous brown arenaceous shale	5
3. Thin band of sandstone bearing fragmentary cheeks of trilobites	4
2. Green shale alternating with grey limestone with a rich, deformed trilobite fauna	26
1. Thin bands of grey limestone	2

The fauna occurs only in horizon 2 where a rich assemblage of trilobites, though deformed, is found. The fauna comprise forms like Blackwelderoides, Parablackwelderia and some unidentifiable cheeks. These forms are closely related to the forms found in horizon 8 of Magam section, therefore, represent same age i.e., early Late Cambrian.

Trahagam Formation is overlain by Marhaum Formation which is lithologically as well as faunistically different from all other formational units of Pohru Group. It comprises dark grey micaceous sandstone and greenish - grey quartzose graywacke with thin bedded argillaceous sediment association which is commonly pyrite bearing. The graywacke is mostly graded bedded.

These rocks are exposed in the core of Marhaum syncline. This Formation has yielded rich shelly fauna of Ordovician age. This fauna is, however, outside the scope of the present work.

#### SPITI :

The Cambrian System in Spiti forms a part of a nearly complete succession of sedimentary rocks from Cambrian to Cretaceous. These rocks are best exposed in the south-western part of Spiti and represent a good example of sedimentation on a platform. The sedimentation in this basin starts with Late Precambrian. An enormous thickness of metasediments constitutes the lower part of this sequence. Presence of pronounced cross-stratification, universally noticeable in these detrital rocks, is indicative of shallow water deposition. Absence of fossils precludes any conclusions regarding the exact age and the environment of deposition. The base of sedimentary rocks is formed by crystalline and metamorphic rocks. The granite and granitic gneisses outcrop intermittently within the metamorphics in the region south of Spiti Valley.

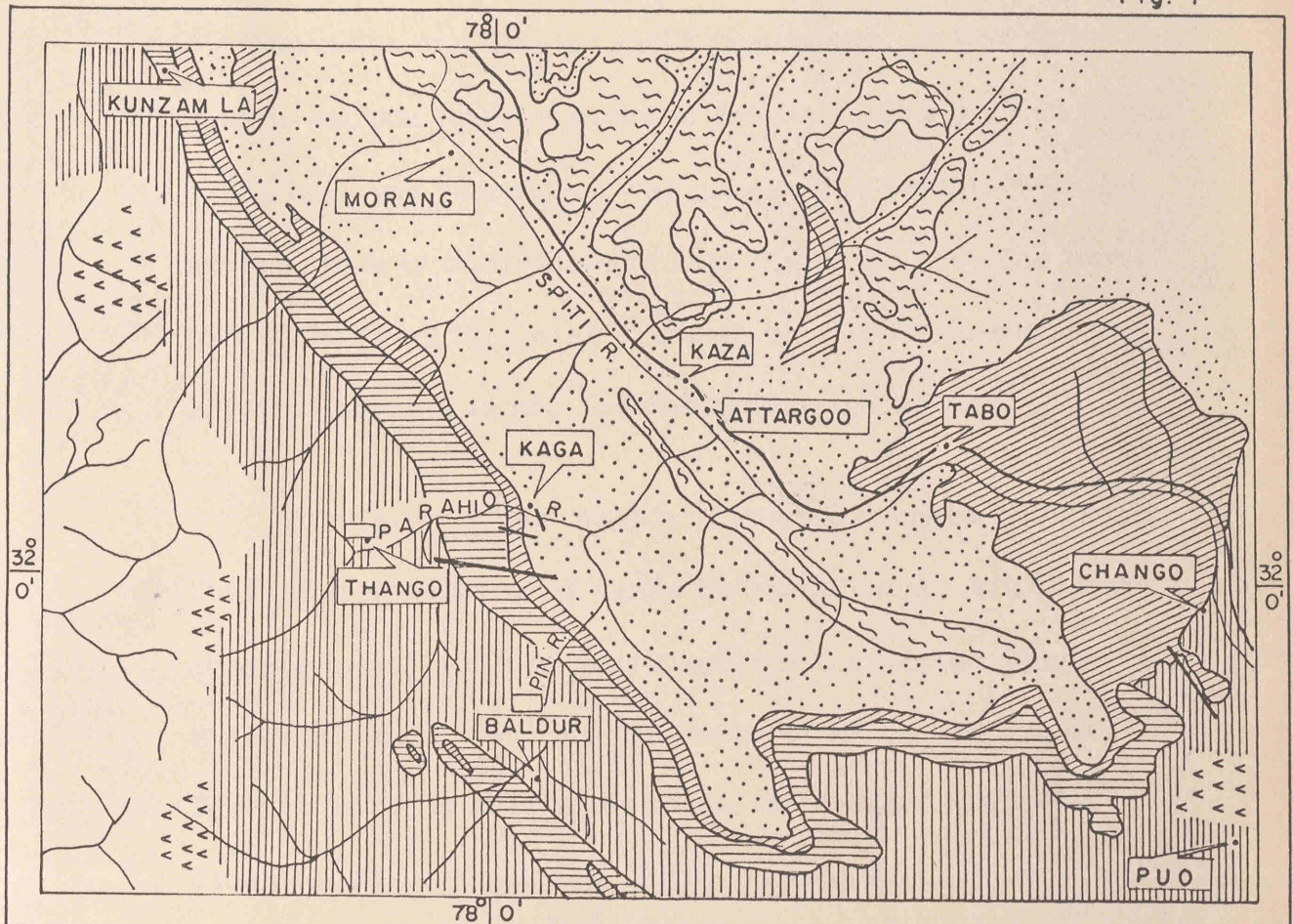
Because of the absence of any Tommotian fauna

Precambrian - Cambrian boundary cannot be identified. The Cambrian System in Spiti is represented by an enormous thickness of sedimentary rocks which comprises ferruginous shale, chloritic phyllite, red quartzite with intercalated grit. They are followed by black, purple and grey shale and brown quartzite. The rusty ferruginous shale is a characteristic landmark in this region. Upwards, the shale becomes more siliceous, is highly cleaved and grades into micaceous quartzite and dolomite. The best exposures of Cambrian rocks in Spiti are in Parahio and Pin sections ( Fig. 4 ) where these rocks have yielded a rich fauna of trilobites and brachiopods, the trilobites being dominant. Some unidentifiable deformed trilobites have also been reported from Takche Formation in Kunzam La section ( Ranga Rao et al., 1982 ). Because of richness of fauna both Parahio and Pin sections were taken for detailed studies. The fauna and sedimentary structure present there indicate sedimentation in a shelf environment. Each of these two sections is discussed separately.










#### Parahio Section :

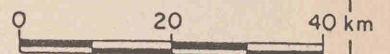
In the Parahio Valley near Thango ( on the left bank of river Parahio ) a classical section, comprising the middle

Fig. 4



I N D E X

- |  |  |
|--|--|
|  CRETACEOUS                     |  MUTH QUARTZITE |
|  SPITI SHALES & KIOTO LIMESTONE |  HAIMANTA GROUP |
|  LILANG GROUP                   |  GRANITE        |
|  KULING & KANAWAR GROUP         |  FAULTS         |
|  AREA OF STUDY                  |  |



(After H. H. Hayden, 1904)

GEOLOGICAL MAP OF SPITI SHOWING THE AREAS OF STUDY

and upper part of "Parahio Series" ( Hayden, 1904 ), succeeded by Ordovician and Silurian rocks is exposed. It was from Parahio section that the first and detailed account of Cambrian of a Himalayan succession was given. The Parahio " Series" exposed here is of Middle and Late Cambrian age. The lower part of the "Parahio Series", corresponding to Griesbach's Middle Haimanta is not fossiliferous in the section.

The Cambrian succession of Parahio overlies conformably the Precambrian elements of the Haimanta Group. Infact in the absence of any distinct Early Cambrian fauna in the sequence, the Precambrian- Cambrian boundary cannot be demarcated. The first body fossils appearing in the sequence comprise brachiopods and trilobites which have distinct Middle Cambrian affinities. Reed ( 1910) has reported a cephalon of Redlichia noetlingi from a transported boulder in Pin Valley but there is no record of any Early Cambrian trilobite from Parahio section.

The succession consists chiefly of quartzite and shale of varying colours. The lower - most beds of the fossiliferous sequence comprise dark -brown quartzite and shale, varying from a soft argillaceous rock to a hard siliceous and finely laminated variety. The direction of foliation is generally oblique

to the bedding. The shales are interbedded with great regularity by grey or whitish quartzite which is invariably capped by a narrow band of dolomitic limestone. Towards the top of the series argillaceous beds give place to quartzite with bands of dolomite, which gradually increase in frequency, till they become the predominant rock.

These beds constitute the oldest fossiliferous series hitherto found in Spiti. There is a distinct angular unconformity towards the top marked by a conglomerate horizon. This unconformity eliminates a major part of the Late Cambrian and only early part of Late Cambrian is present. After this unconformity the entire facies of rocks is different in the overlying Ordovician sequence which is generally unfossiliferous.

The sequence of rocks in this section along with their thickness is as under :-

		Thickness ( in metres )
19.	Conglomerate	15
18.	Quartzite and siliceous shale	26
17.	Quartzite with bands of shale capped by dolomite	34
16.	Sandstone, quartzite and siliceous shale.	48
15.	Grey dolomite weathering brownish red	9
14.	Quartzite with interbedded shale	26
13.	Shale with trilobite	10
12.	Quartzite with bands of shale	27
11.	Dark grey quartzite	17
10.	Shale with trilobites	9
9.	Dark grey quartzite	15
8.	Shale with trilobites	22
7.	Dark grey quartzite	9
6.	Shale with trilobites and brachiopods	6
5.	Grey quartzite	4
4.	Shale with trilobites	3
3.	Quartzite with bands of shale	23
2.	Shale with trilobites	2
1.	Reddish brown quartzite with bands of shale	Exposed 98

The fauna was collected from different stratigraphic levels and eight fossiliferous horizons were broadly located. Although the entire sequence is fossiliferous, better preservation is available in these horizons. Generally the fossils are deformed and occasionally they are crushed. The best preservation is available from fine shale. The trilobite remains are clustered along some bedding planes where the moulted off exoskeletons belonging to various stages of metamorphosis are found.

The fossils were collected from eight different horizon numbered 1, 2, 4, 5, 6, 8, 10 and 13 which are indicated in the lithostratigraphical column. As the horizon no 10 has yielded a rich assemblage of Ptychoparia, which is characteristic of middle part of Middle Cambrian, so only the fauna collected above this horizon is taken for detailed study. Above Ptychoparia horizon there is only a single horizon i.e. bed no. 13 which has yielded a rich trilobite fauna of early Late Cambrian age. The faunal assemblage from this horizon comprises Olenus haimantensis, Hundwarella interpres, H. rushtoni, Spitella barachuda, ?Anomocarella sp. and Tsinania sp.

Pin Section :

The Pin section comprising the "Parahio Series " ( Hayden op. cit. ) followed by Ordovician and Silurian is exposed on the right bank of river Pin near Shian and Baldor, a few Kilometres south of village Muth. This section is the south east extension of Parahio section and comprises chiefly quartzite, shale, limestone and conglomerate of varying colours. The lowermost beds of the sequence exposed from Baldor to Shian consist of dark brown quartzite intercalated with dark shale. These beds, though having a massive thickness, are devoid of any body fossils. However, a variety of trace fossils have been found which suggest an Early Cambrian age. Redlichia noetilingi has been reported by Reed ( 1910 ) from a transported block in this section, but no subsequent worker was able to locate this unit in situ. These rocks are overlain by grey quartzite intercalated by shale which have yielded Middle Cambrian fossils near Shian. The fauna consists chiefly of inarticulate brachiopods and trilobites but trilobites are predominant. The fauna occurs in two very narrow bands, each about half a metre thick from horizon nos. 6 and 8 of the lithostratigraphic column and comprises Oryctocephalus and Pagetia, two trilobite genera characteristic of middle part of

Middle Cambrian, which can also be located in Parahio section. Above this a huge thickness of quartzite about 270 metres alternating with shale are found which are devoid of any fossils. The massive thickness of unfossiliferous rocks in turn is overlain by reddish brown conglomerate representing an unconformity. Overlying this conglomerate is dark brown Shian quartzite. The Pin section is identical to Parahio section lithologically except for absence of dolomite but faunistically where the Parahio section is very rich in fossils, Pin section has yielded very scarce fauna.

The sequence of rocks in this sections is as follows :-

		Thickness <u>(in metres )</u>
10.	Reddish brown conglomerate	20
9.	Alternating bands of quartzite and shale	270
8.	Shale with trilobites	0.5
7.	Dark grey quartzite	35
6.	Dark grey shales containing a small band 0.5 m bearing trilobites	15
5.	Dark grey quartzite alternating with shale	190

4.	Quartzite	40
3.	Dark shale and quartzite with trace fossils	10
2.	Quartzite	15
1.	Black quartzite with shale	Exposed 30

CHAPTER - IV  
BIOSTRATIGRAPHY OF THE LATE MIDDLE  
CAMBRIAN AND LATE CAMBRIAN

Before the commencement of D.S.T. sponsored project, "Biostratigraphy of the Cambro -Triassic Sequences of Tethys Himalaya " of which the present work forms a part, no systematic biostratigraphic classification was available especially in Spiti. In Kashmir some work on the Cambrian biostratigraphy was done by Shah ( 1982 ), Shah and Sudan ( 1983, 1984 ) which particularly relates to Middle Cambrian. The Late Cambrian was recorded in

these publications but the fauna was not described.

The Cambrian biostratigraphic classification given here, which is purely based on the trilobites, is a considerable improvement on the existing position in Kashmir and almost entirely new for Spiti. It leaves several gaps in the sequences in both the areas, which are either represented by barren zones or by periods of non-deposition. The present classification includes those parts of the sequence where intra-System boundaries could possibly be marked.

In Kashmir the biostratigraphic zonation given by Shah ( 1982 ), Shah & Sudan ( 1983, 1984 ) is given below in Table A, with Damesella Zone being the youngest.

TABLE - A

Damesella Zone

Damesella shergoldi, Blackwelderiodes monkei,  
Dikelocephalites flabelliformis, Litocephalus sharmi.

Bolaspidella Zone

Bolaspidella himalayensis, B. magamensis, Bolaspidella  
sp.

Anomocare - Bailiella Zone

Anomocare suspectum, A. perfunctum, Bailiella sejuncta, B. frangtengensis, Holocephalina wadai,  
H. wakhalo, Conocoryphe reedi, Peronopsis, Hypagnostus

Tonkinella - Anomocare Zone

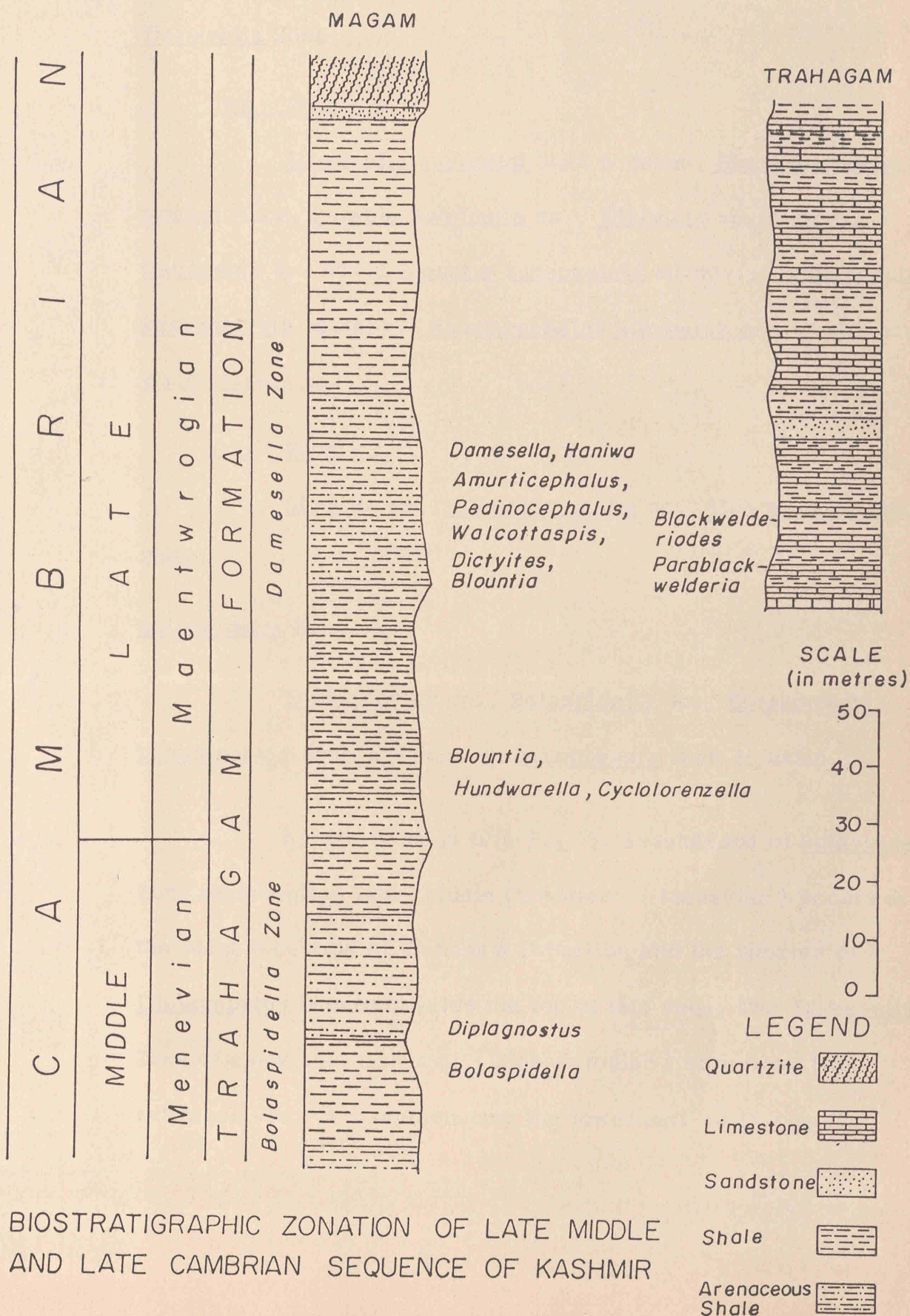
Tonkinella, Hundwarella, Anomicare dimotum,  
A. hundwarensense, Ptychoparia dardpurensis, Peronopsis

Solenopleura - Tonkinella Zone

Solenopleura, Ptychoparia, Tonkinella, Hundwarella.

All the above mentioned Zones are assemblage zones and are overlapping. During the course of present studies fauna collected from Bolaspidella and overlying zones only is taken for detailed study as shown in Fig. 5. Though the two zonal names viz., Bolaspidella Zone and Damesella Zone as has been proposed by Shah and Sudan (op. cit.) representing late Middle to early Late Cambrian, have been retained, several new faunal elements which constitute the assemblages of these two zones are being reported for the first time, as is shown in Table - B.

Fig. 5



BIOSTRATIGRAPHIC ZONATION OF LATE MIDDLE AND LATE CAMBRIAN SEQUENCE OF KASHMIR

TABLE - BDamesella ZoneSub - Zone - B

Damesella shergoldi Shah & Sudan, Blackwelderiodes monkei Hupe, Parablackwelderia sp., Dictyites sp., Haniwa transversa sp. nov., Blountia subanquilata sp. nov., Pedinocephalus kashmirensis sp. nov., Amurticephalus elongatus gen. et sp. nov., Walcottaspis sp.

Sub - Zone - A

Blountia sp., Cyclolorenzella sp., Hundwarella kingi Sudan.

Bolaspidella Zone

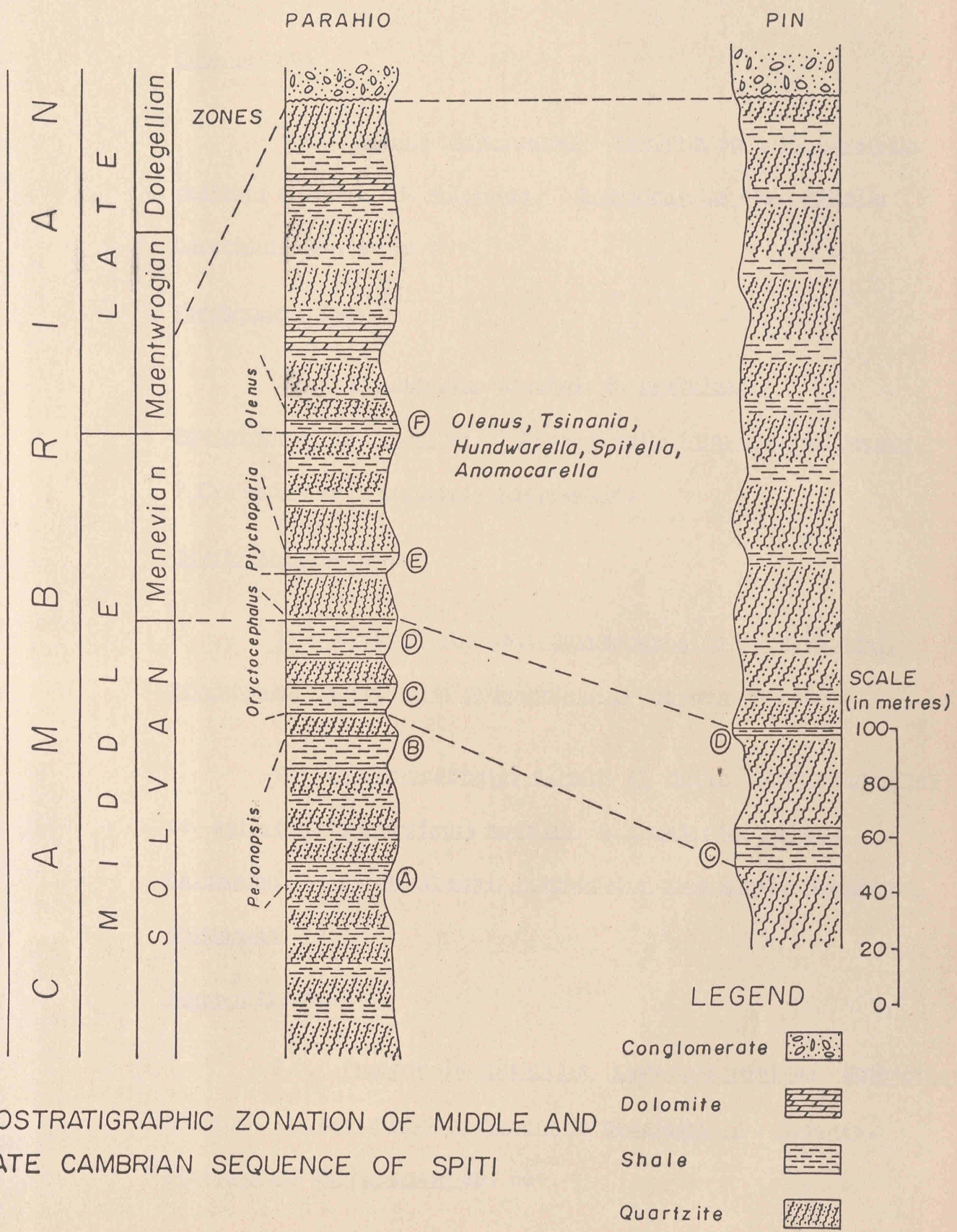
Diplagnostus sp., Bolaspidella sp., Bolaspidella himalayensis Shah & Sudan, B. magamensis Shah & Sudan.

As can be seen from Fig. 5, assemblage of Bolaspidella Zone representing late Middle Cambrian (Menevian) occurs in the Magam section of Trahagam Formation and the species of Diplagnostus occurs towards the top of this zone. The Damesella Zone of early Late Cambrian (Maentwrogian) comprises two subzones viz., A - representing the lower part of Damesella

Zone and containing species of Blountia, Hundwarella, Cyclolorenzella, occurring in the Magam section and indicating the start of Late Cambrian, and B - having Blackwelderiodes, Parablackwelderia from the Trahagam section and the remaining faunal elements from the Magam section as given in the Table - B above.

During the course of present work in Spiti ( Fig. 6 ) a rich trilobite assemblage from middle part of Middle Cambrian (Solvan ) to early Late Cambrian ( Maentwrogian ) has been found. It comprises six assemblages in Parahio section and two in Pin section . All these assemblages have been grouped into four assemblage zones. The fauna overlying the Ptychoparia Zone which is represented by a single Olenus Zone, is taken for detailed study and is described systematically. The detailed systematic description of the lower three zones is outside the scope of the present work. The identification of fauna which constitutes the assemblage of these three zones is based on the work carried out by my colleague Dr. Sat Paul ( personal communication ). However, for the sake of continuity, all the assemblage zones and their assemblages in Spiti are given in Table - C, which include the contributions made in the present work.

Fig. 6



BIOSTRATIGRAPHIC ZONATION OF MIDDLE AND LATE CAMBRIAN SEQUENCE OF SPITI

## TABLE - C

Olenus Zone

F - Olenus haimantensis, Tsinania sp., Hundwarella rushtoni sp. nov., H. interpres, ? Anomocarella sp., Spitella barachuda gen. et sp. nov.

Ptychoparia Zone

E - Ptychoparia strachei, P. pervulgata, Eosoptychoparia Kochibei, ? Anomocarella (Entorachis) memor, ? Eymekops sp., Lyriaspis maopoensis.

Oryctocephalus Zone

D - ? Kochiella sp., Oryctocephalus cf. reynoldsi, Ptychoparia consocialis, Solenopleurina haydeni sp. nov.

C - Oryctocephalus salteri, O. opiki, Oryctocephalites cf. sulcatus, Solenopleura hostilis, S. praeterita, Pagetia haimantensis, P. griesbachi, Ptychoparia consocialis, Lyriaspis spitiensis.

Peronopsis Zone

B - Peronopsis spitiensis, Lyriaspis admissa, Solenopleura hostilis, Lyriaspis civica, Annamitia himalaica, A. defossa, Alokistocare thangoensis sp. nov.

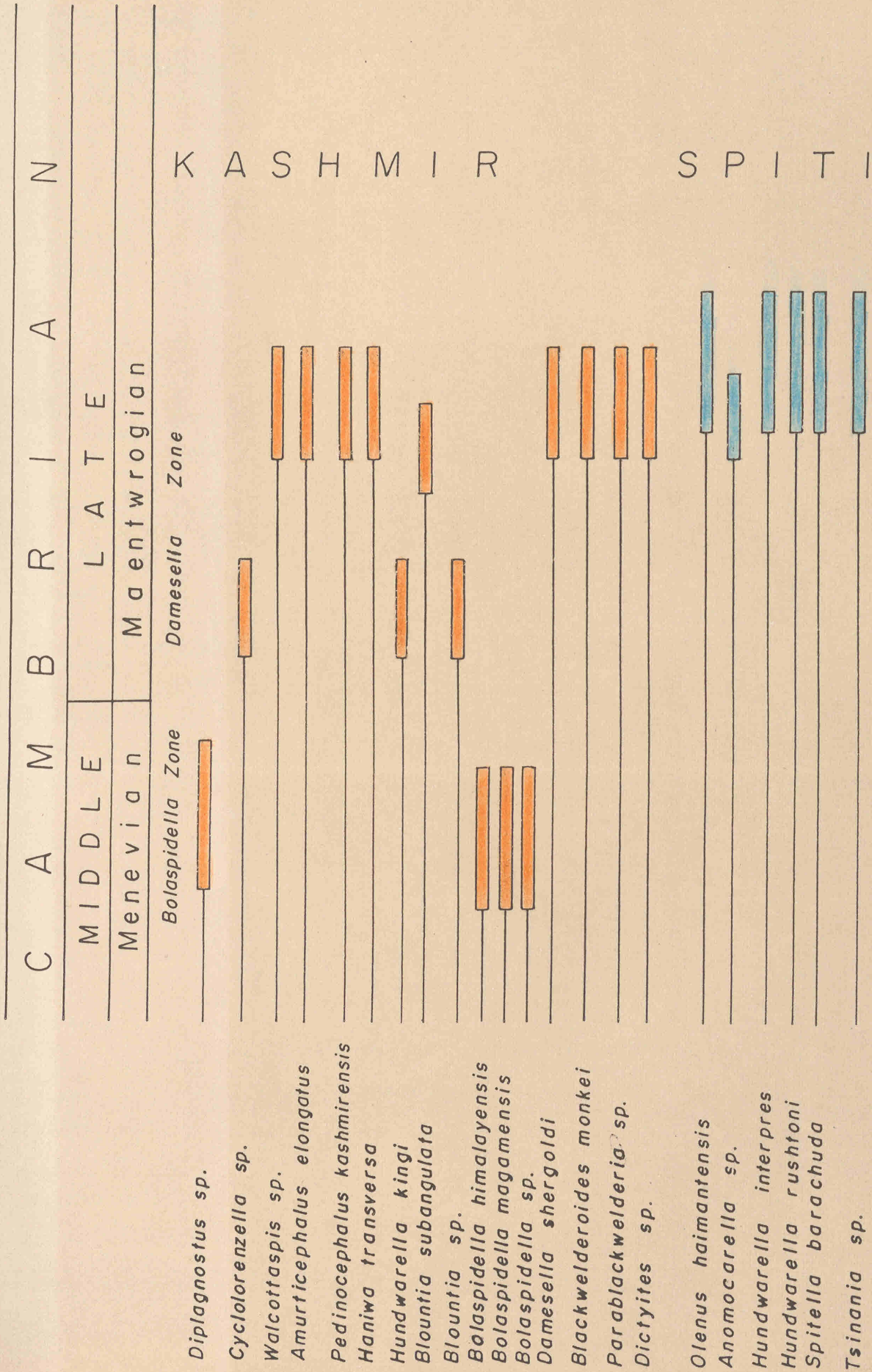
A - Peronopsis spitiensis, Lyriaspis spitiensis

From Fig. 6 it is seen that there is an approximately forty metre barren zone between Olenus and Ptychoparia Zones. While the former represents early Maentwrogian the latter is known to occur in the middle part of Menevian. Only the early Late Cambrian is represented here while the middle and late part of the Late Cambrian and a major part of Early Ordovician is eliminated by a distinct angular unconformity represented by a conglomerate horizon. Overlying the conglomerate horizon the rocks represent an entirely different facies and have yielded middle Ordovician brachiopods.

The interpreted ranges of trilobite genera in the Middle and early Late Cambrian of Kashmir and Spiti are shown in Fig.7.

Attempts have been made to correlate the assemblage zones of Kashmir and Spiti with the known zones of Cambrian (starting from Middle Cambrian onward) at global and regional level ( Fig. 8 ).

The present biostratigraphic studies have clearly indicated that the earlier impression that faunas of both Kashmir and Spiti are endemic ( Reed, 1910, 1934 ; Pascoe, 1959 )



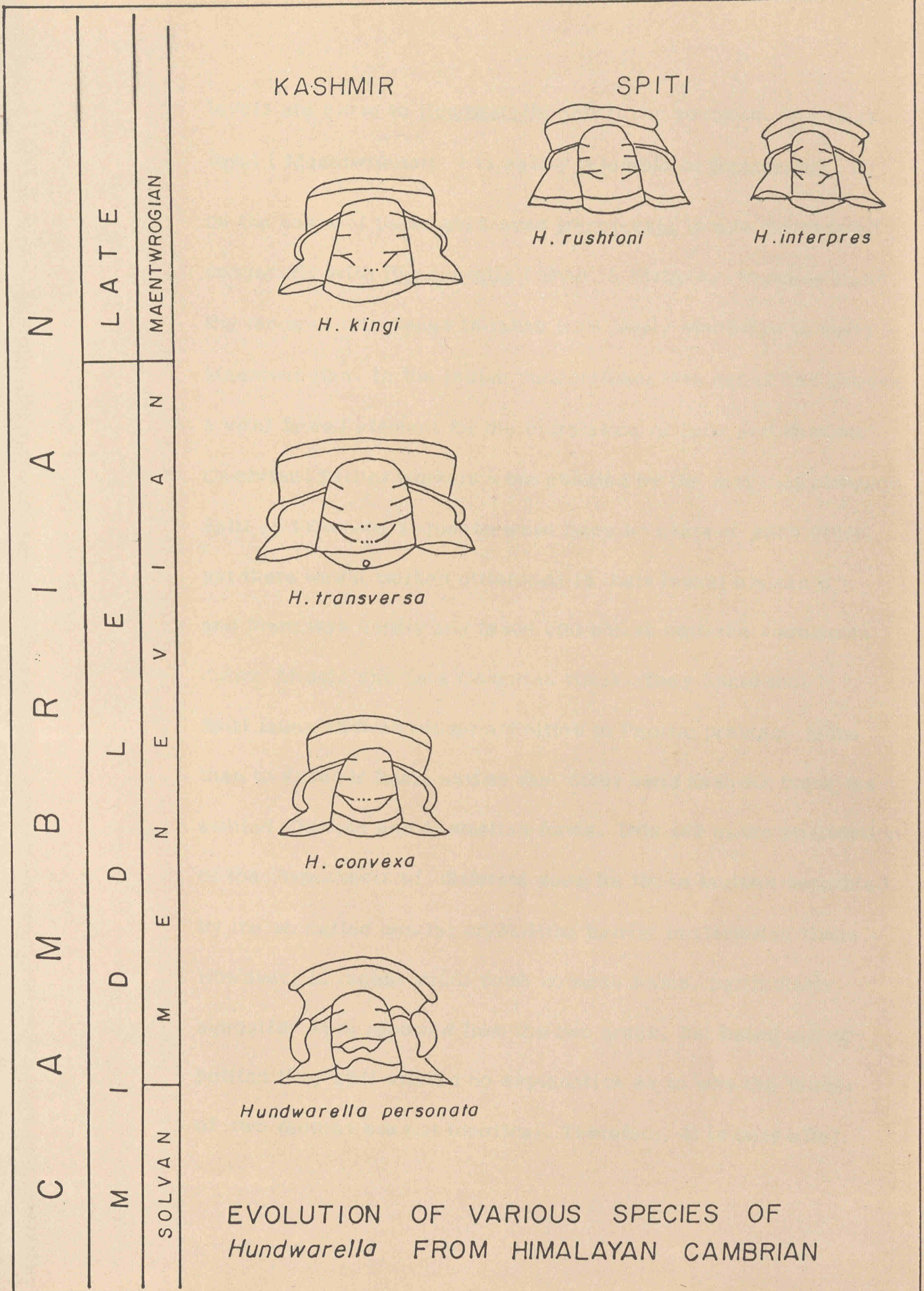
RANGES OF THE LATE MIDDLE AND LATE CAMBRIAN TAXA FROM KASHMIR AND SPITI

to the respective areas is not entirely true and there is similarity between the fauna of Kashmir and Spiti atleast at the generic level. The identical genera include Solenopleura, Hundwarella, Anomocarella, Anomocaraspis, Ptychoparia etc. Even in some cases the similarity is at the specific level, for example in species of Peronopsis and Pagetia.

The detailed biostratigraphy from the topmost part of Menevian onwards is discussed below :

#### Late Middle Cambrian

The occurrence of Hundwarella is of special significance. This genus was first described by Reed ( 1934 ) from Middle Cambrian of Kashmir. Subsequently, an allied genus Iranoleesia was reported from early Late Cambrian of Iran ( King, 1955 ). Several species of both the genera were described from several parts of southern and eastern Asia ( Kobayashi, 1962 ; Gupta and Suneja, 1977 ; Sudan, 1982 ). During the course of present studies the find of three new species of Hundwarella from Kashmir and two new species from Spiti helped in establishing an evolutionary gradation in different species of Hundwarella. Fig. 9 shows that species occurring at the lower stratigraphic



EVOLUTION OF VARIOUS SPECIES OF *Hundwarella* FROM HIMALAYAN CAMBRIAN

levels are close to Hundwarella and at the youngest stratigraphic level ( Maentwrogian ) is easily referable to Iranoleesia. So on the basis of these evidences Iranoleesia is now considered congeneric with Hundwarella ( Shah & Kishore, in press ) and the range of this genus is taken from early Menevian to early Maentwrogian. In the Indian subcontinent this genus has become a vital faunal element for the correlation of Spiti and Kashmir Cambrian. Earlier workers were puzzled by the fact that although Spiti and Kashmir sequence were lying so close to each other, yet there was a marked difference in their faunal elements and there was hardly any taxon common to both the sequences during Middle and Late Cambrian times. They found that Spiti fauna showed closer affinities to Pacific province fauna than to Kashmir fauna and on the other hand Kashmir fauna resembled Chinese and Australian forms. This led to the postulation of the hypothesis of different seas for these regions separated by the so called central crystalline barrier in Cambrian times. However, in recent years some common forms, particularly agnostids were reported from the two areas, but being cosmopolitan they still offered no explanation as to why the faunas of two regions are not identical. Therefore, it is only after

the discovery of several species of Hundwarella from Kashmir and Spiti that we come across certain evidences which clearly indicate that Kashmir and Spiti regions were the parts of same sea and there is a continuity in the two basins.

Towards the top of Middle Cambrian and early Late Cambrian the trilobite forms which flourished in Early Cambrian and attained their peak during Middle Cambrian died rapidly and new forms emerged. This reorganisation of trilobite families is a global trend and is well exhibited in Kashmir and Spiti but is more pronounced in Kashmir.

Bolaspidella Zone represents the top most part of Middle Cambrian in Kashmir. The occurrence of different species of Bolaspidella from this zone have a special significance because this genus is a typical American element, and is probably the only known occurrence in Asia. It was first reported from Kashmir by Shah and Sudan ( 1982 ). Thereafter a considerable debate followed whether the Kashmir form could be included in Bolaspidella ( Kumar, 1983 ; Shah, 1983 ) but the controversy has eventually been resolved through biometric studies ( Shah et al., 1985 ). However, recently Jell (1986 ) while questioning the assignment of different species from

Kashmir to Bolaspidella ( Shah & Sudan op. cit. ) suggested that the Kashmir forms probably belong to families Inoyiidae and Wuaniidae which are characteristic of early Middle Cambrian in China . But the Bolaspidella Zone from Kashmir cannot be assigned an early Middle Cambrian age because the fauna in the underlying Anomocare - Bailiella Zone is characteristic of middle Middle Cambrian and the discovery of Diplagnostus sp. in this zone during present work is of special significance. Diplagnostus is known to occur in Leipyge laevigata Zone in Australia ( Opik, 1967 ), in Sweden ( Daily and Jago, 1975 ) and in the Yangliugang Group of Chiangnan Belt ( Chang, 1980 ) that extends from South Korea across south western China into North Vietnam. In North America also species of Diplagnostus are reported from Leipyge laevigata Zone ( Robison, 1984 ). Secondly it is overlain by subzone - A of the Damesella Zone in Kashmir ( Table - B, Fig.5 ) which contains a characteristic genus Cyclolorenzella, which is reported in China from the Kushan stage of early Late Cambrian age ( Chang op. cit. ) . This genus has also been reported from the Taitzuan Formation ( early Late Cambrian ) in Korea ( Kobayashi, 1960 ) and

from Agnostus pisiformis Zone of Outwood Formation in Britain ( Rushton, 1978 ).

In North America the Bolaspidella Zone has recently been divided into three subzones on the basis of agnostids viz., Ptychagnostus atavus, P. punctuosus and Lejopyge laevigata and represents the latest Middle Cambrian. The boundary between Middle and Late Cambrian has differently been fixed by various workers in North America. Lochman - Balk ( 1971 ) opined that Bolaspidella Zone possibly extends upto the early Late Cambrian. This was suggested on the basis of some genera which appear in association with the immediately earlier faunal assemblages. For example Modocia first appears in the Bolaspidella Zone and passes onto the Cedaria Zone. Robison ( op. cit. ) supported the conclusions of Daily and Jago ( 1975 ) who mentioned that Cedaria Zone which overlies the Lejopyge laevigata is of Middle Cambrian age and also, the lower part of Dresbachian stage in North America represents Middle Cambrian. However, considering the position of Lejopyge laevigata in other well known Cambrian sequences, a majority of workers fix the Middle and Late Cambrian

boundary in North America at the end of Bolaspidella Zone (Palmer, 1971, 1979 ; Harland et. al., 1982 ). So in Kashmir in the absence of Lejopyge laevigata this boundary can still be fixed at the top of Bolaspidella Zone, because of the occurrence of Diplagnostus, a genus known to be found in association with L.laevigata as mentioned earlier.

Unlike Kashmir where the fauna is overlapping in different biostratigraphic zones, an entirely different situation exists in Spiti. Here the fauna during Cambrian is not distributed as a continuum, but the sequence is invariably punctuated with considerable thicknesses of unfossiliferous strata. As a result the fauna of one horizon seems to be completely distinct from the next and often bears apparently unrelated forms. Therefore, the Middle and Late Cambrian boundary in Spiti cannot be precisely fixed. Here the youngest Middle Cambrian is represented by Ptychoparia Zone, which is characteristic of middle Middle Cambrian and the next faunal horizon after approximately forty metres of barren strata yield trilobite forms which are typical of early Late Cambrian (Fig.6 ). So the Middle and Late Cambrian boundary in Spiti lies somewhere in this barren part

between these two zones.

Late Cambrian :

In Kashmir Damesella Zone representing the Late Cambrian overlies the Bolaspidella Zone. This Late Cambrian assemblage zone is marked in the Trahagam Formation which includes the trilobite assemblage as shown in Table - B.

The presence of Damesella in this zone is very significant because it represents the occurrence of an important early Late Cambrian faunal element in Kashmir. This genus is a characteristic element of the Australo - Asian Super region and has been reported besides Kashmir, in China, Iran, Australia and Kazakhstan. However, the stratigraphic position of Damesella in Kashmir is somewhat different from the level of occurrence in some other areas. In China Damesella occurs in the topmost zone of Chuangia stage of late Middle Cambrian. This is overlain by the Blackwelderia Zone of Kushan stage which is early Late Cambrian. The age of Kushan stage of China has been a topic of considerable debate. Willis, Blackwelder and Sargent ( 1907), Walcott ( 1914 ), Kobayashi ( 1935 ) and

Endo ( in Resser & Endo, 1937 ) tended to consider it as the uppermost part of Middle Cambrian, while Monke ( 1903 ), Sun ( 1948 ), Lu & Dong ( 1953 ), Chang ( 1957 ) and Chu ( 1959 ) were of the view that it represents lowermost Upper Cambrian. Opik ( 1967 ) and Daily & Jago ( 1975 ) have discussed the correlation of the three zones of the Australian Mindyallan stage that is Erediaspis eretes, Cyclagnostus Quasivespa and Glyptagnostus stolidotus with the Blackwelderia and Drepanura Zones of the Kushanian of China. The occurrence of Bergeronites and Stephanocare in both Black welderia Zone of China and Cyclagnostus Quasivespa Zone of Australia has been presented as an evidence by Daily and Jago ( op. cit. ) for drawing the Middle and Late Cambrian boundary in China at some point within the Blackwelderia Zone. Chang ( 1980 ), however, considered the views expressed by Daily & Jago ( op. cit. ) as premature and suggested that it is most suitable to draw Middle - Late Cambrian boundary in China at the base of Blackwelderia Zone, which approximately coincides with the base of Agnostus pisiformis Zone of Europe.

In Australia Damesella occurs in Damesella torosa - Ascionepea janitrix Zone which has been referred as Zone of

Passage by Opik ( op. cit. ) . He suggested that word passage is used to indicate that the Zone cannot be assigned wholly to the Middle, nor to the Late Cambrian but represents the boundary between the two series or simply the passage from one epoch to another. So the Damesella in Australia occurs at slightly higher stratigraphic level and its reported occurrence from Iran exhibit the same position which it occupies in Australia.

Ivshin ( 1962 ) has reported the occurrence of Damesella from the Agnostus pisiformis Zone of early Late Cambrian from Altai - Sayan region of the Siberian platform. So the Damesella Zone of Kashmir can be correlated with the Agnostus pisiformis Zone of Europe, Glyptagnostus stolidotus Zone of Mindyallan stage of Australia, Blackwelderia Zone of Kushanian stage of China and Upper Cedaria -Crepicephalus Zone of North America on the basis of typical faunal elements of these zones which are found in the Damesella Zone of Kashmir. Cyclolorenzella occurs in the Blackwelderia Zone of China ( Chang op. cit.) as well as from the Agnostus pisiformis Zone of England ( Rushton, 1978 ). Blountia is reported from Glyptagnostus stolidotus Zone of Australia ( Opik op. cit.) and Crepicephalus Zone of Kazakhstan

( Ivshin, op. cit. ). In North America it ranges in age from middle Cedaria to lower Aphelaspis Zones ( Lochman - Balk, 1971 ). The genera Blackwelderiodes and Parablackwelderia occurs in the Blackwelderia Zone of China ( Chang op. cit. ), Korea and Vietnam ( Kobayashi, 1967 ), Afghanistan and Iran ( Wolfart, 1981 ). Crepicephalus and Paracoosia, the typical North American Elements of Crepicephalus Zone have been reported from the Blackwelderia Zone of Iran and Afghanistan ( Wolfart and Kursten, 1974 ). Pedinocephalus occurs in the Crepicephalus Zone of Kazakhstan ( Ivshin, op. cit. ). Blandicephalus which is very close to the new genus Amurticephalus from Kashmir occurs in the lower part of Aphelaspis Zone of North America ( Palmer, 1954 ).

However, the Damesella Zone of Kashmir cannot be correlated with the Olenus Zone of Spiti because, except for Hundwarella, there is no other form common in both the Zones even at generic level. This can be explained by the fact that Olenus Zone of Spiti occurs at slightly higher stratigraphic level than the Damesella Zone of Kashmir. This is also evident from the species of Hundwarella from Olenus Zone ( Fig. 9 ), which shows a higher level of evolution than Hundwarella kingi

which occurs in the Damesella Zone of Kashmir. This has been discussed in detail by Shah & Kishore ( in press ). Secondly, the Olenus Zone in Scandinavia ( Henningsmoen, 1957 ; Martinsson, 1974 ) overlies the Agnostus pisiformis Zone as is the case in Wales and England ( Rushton, 1974 ). Olenus Zone is considered equivalent to Aphelaspis Zone of North - America .

Regarding the fixation of Cambrian and Ordovician boundary, it can neither be drawn in Kashmir nor can it be fixed in Spiti. In Kashmir after the Damesella Zone which is early Late Cambrian, a massive thickness of rocks, consisting of alternating bands of shale and limestone occurs, which is unfossiliferous. The next faunal unit overlying these rocks has yielded Middle Ordovician brachiopods. Though the rocks are apparently continuous, yet there is a faunal gap from middle Late Cambrian to Early Ordovician. Thus, the boundary between Cambrian and Ordovician cannot be precisely fixed. To date infact, nowhere in Kashmir have any taxa which definitely belong to the middle and late Late Cambrian been reported. The report of Saukia ( Reed, 1934 ) which is a characteristic late Upper Cambrian form is erroneous and it is a ptychoparid collected at a much lower stratigraphic level ( Shah, 1982 ).

In Spiti the picture is more clear because after the Olenus Zone there is a distinct angular unconformity represented by reddish brown conglomerate, which probably accounts for the elimination of entire middle Late Cambrian to Early Ordovician in this area. After this unconformity, here the facies shows a marked change and next faunal unit yields Middle Ordovician brachiopods. This unconformity has also been reported from China where it has a very limited span and from Iran and Afghanistan ( Wolfart, 1981 ). This break represents a most significant episode which marks the end of the transgressive phase of sedimentation in Spiti as well as in the Tethys Himalaya ( Garazanti et al., 1986 ), since it has attained a regional significance, because it marks a diastrophic event not only in the entire Asiatic region but also in different parts of Gondwandland like parts of Africa, Australia and Antarctica. Some authors prefer to call it an Orogenic phase ( Pan - African Orogenies of Powell and Conaghan, 1973; Baud et al., 1984 ).

CHAPTER - V  
SYSTEMATIC PALAEOLOGY

As discussed earlier, the fauna collected from Bolaspidella and overlying horizons in Kashmir and that overlying the Ptychoparia horizon in Spiti is being systematically described. The preservation is, on the whole good in both the regions, though it is better in Kashmir. Some

deformation is also noticeable in some specimens. Whereas the bulk of material in Kashmir consists chiefly of isolated cephalons and very few pygidia, in Spiti some complete articulated exoskeletons are also available. The repository of the material is the Palaeontological Museum of Department of Geology, University of Jammu. The classification followed is that adopted in the "Treatise on Invertebrate Palaeontology" (Moore, 1959).

The systematic palaeontology contains the description of nineteen trilobite taxa out of which only one is an agnostid and the rest are polymerids. These include one new genus and four new species from Kashmir and one new genus and two new species from Spiti. Except for Olenus haimantensis from Spiti and Damesella shergoldi, Blackwelderioides monkei, Hundwarella kingi and various species of Bolaspidella, all other forms are being reported for the first time from the respective areas. Bathyriscus ? stoliczkai and Dicellocephalus ? interpres already reported by Reed (1910) from Spiti, are grouped together and given a generic shift as Hundwarella interpres.

The different species of Bolaspidella from Kashmir are not being systematically described in the present work as these have already been discussed in detail by Shah and Sudan (1982) and Shah et al. ( 1985 ).

CHECK - LIST

Diplagnostus sp.

Cyclolorenzella sp.

Walcottaspis sp.

Amurticephalus elongatus gen. et sp.nov.

Pedinocephalus Kashmirensis sp.nov.

Olenus haimantensis Reed

Haniwa transversa sp.nov.

? Anomocarella sp.

Hundwarella kingi Sudan

Hundwarella interpres ( Reed )

Hundwarella rushtoni sp. nov.

Spitella barachuda gen. et sp. nov.

Blountia subangulata sp.nov.

Blountia sp.

Damesella shergoldi Shah & Sudan

Blackwelderiodes monkei ( Walcott ) Hupe

Parablackwelderia sp.

Dictyites sp.

Tsinania sp.

Phylum	:	ARTHROPODA
Subphylum	:	TRILOBITOMORPHA
Class	:	TRILOBITA
Order	:	AGNOSTIDA Kobayashi, 1935
Suborder	:	AGNOSTINA Salter, 1864
Family	:	DIPLAGNOSTIDAE Whitehouse, 1936
Subfamily	:	DIPLAGNOSINAE Whitehouse, 1936
Genus	:	<u>DIPLAGNOSTUS</u> Jaekel, 1909

Diplognostus sp.

Plate A, 1-4 ( all cephalata ),  
5-10( all pygidia ),

Material :

Ten cephalata and twelve pygidia, very poorly preserved  
in blocks of green shale.

Description :

Cephalon subquadrate to semicircular in outline,

slightly wider than its length, moderately convex, gently rising from the border at sides. Border narrow, convex, running all along the cephalon and maintains nearly a constant width. Faint to nearly obsolete longitudinal preglabellar median furrow ; axial furrow well marked and deep, border furrow comparatively shallow; glabella quite distinct, more convex and raised than the cheeks, Sub - cylindrical, narrowing little anteriorly to almost parallel sided, glabella is about three quarters and one third the width of the cephalon, glabella bilobed, anteriorly cut off by a transverse furrow as the frontal glabellar lobe, transverse furrow nearly straight; frontal or anterior lobe subquadrate about one-third of the posterior glabellar lobe. As the specimens are exfoliated and very poorly preserved, the presence or absence of nodes on the lobes cannot be determined. Posterior glabellar lobe at the base about one half the width of the cheek; posterior lobe almost oval to sub-cylindrical in shape, glabellar rear gently angulate. Cheeks quite wide, less convex and less raised than the glabella, uniting in front of the glabella, their width nearly equal to that of the glabella at the anterior end. Basal lobes small, subtriangular and almost swollen, resting on the angular indentations caused

by angulate glabellar rear.

Pygidium subquadrate to semi - circular in shape, slightly wider than long ; pygidial axis semi - cylindrical, almost parallel sided, constricted at the middle, gently curving back to a pointed posterior end, length of the axis about two - third that of pygidium and width about half the total width of pygidium; narrow, moderately deep axial furrows; acrolobes narrow, less than one half of the axis width, gently curving and narrowing towards the posterior side, constricted and not joined behind the axis, finish off into pointed shapes; narrow, shallow anterior lateral axial furrow directed inwards and for wards from either end; posterior lateral furrow poorly developed. Pygidial axis having two narrow shallow lateral axial furrows dividing the axis into three segments, first two segments of about equal length and together make up about half the total axial length, a pair of median tubercles on each of first and second axial lobes; border narrow, convex, crescent shaped having nearly a constant width at the posterior side behind the axis.

Dimensions : ( in mm ) see page 92 .

Remarks :

In all its morphological details viz., wider than long cephalon, moderately deep axial furrow, faint incomplete preglabellar median furrow, bilobed glabella and pygidium characterised by relatively long, broad usually poorly segmented axis and crescent shaped border, the specimens correspond to genus Diplagnostus. However, it differs from all the known species of Diplagnostus.

With Diplagnostus cf. humilis reported from Zanskar, Ladakh by Whittington ( 1986 ) the specimens differ in having constricted acrolobes in the pygidium.

D. Planicauda Westergaard ( 1946 ) differs in having a distinct and complete median preglabellar furrow, sharply angulate glabellar rear and scrobiculate cheek.

D. Planicauda bilobatus Kobayashi ( 1939 ) has cheeks without scrobicules and an incomplete or even absent median preglabellar furrow, as is the case in this form but D. planicauda bilobatus has a sharply angulate glabellar rear and a pygidium with a pair of pygidial spines.

D. planicauda vestgothicus Westergaard ( op. cit. ) has scrobiculate cheeks, complete preglabellar median furrow and sharply angulate glabellar rear and D. crassus Opik (1967) differs in having a glabella which is broad and rounded at the rear and a scrobiculate test.

With D. humilis Whitehouse ( 1936 ), D. atavorum and D. floralis Opik ( 1979 ) the resemblance is less close as all of these have scrobiculate test and unconstricted acrolobes in the pygidium.

The preglabellar median furrow of D. jarillensis Rusconi ( 1952 ) is deeper than that of Kashmir form and D. jarillensis also has a more rounded glabellar front.

Robison ( 1964 ) has mentioned that Baltagnostus Lochman ( 1944 ) closely resembles Diplagnostus. This is true of Kashmir form as well. It shows close affinities to Baltagnostus except that in Baltagnostus the anterior glabellar lobe is nearly effaced and general outline of the cephalon is very flat.

Opik ( 1967 ) has suggested that Diplagnostus has

possibly evolved from an early peronopsid because it shows close resemblance to Peronopsis amplaxis and P. interstricta which occur at stratigraphically lower levels than Diplagnostus sp. But Diplagnostus sp. differs in having a faint partial median preglabellar furrow.

Thus the Diplagnostus from Kashmir, differs from all the known species. However, the material is not well preserved to erect a new species.

Horizon and locality :

The fauna was collected from the top of Bolaspidella Zone in the Magam section, from Kupwara district of north - western Kashmir.

	Specimen numbers					
	<u>KHNF-25</u>	<u>KHNF-23</u>	<u>KHNF-43</u>	<u>KHNF-99</u>	<u>KHNF-38</u>	<u>KHNF-40</u>
<u>Cranidium</u>						
Length of cephalon	2.5	3.4	2.8	2.0	2.0	2.4
Width of cephalon	3.1	3.7	3.1	2.1	2.1	2.8
Length of glabella	1.8	2.5	1.8	1.6	1.3	1.8
Length of frontal lobe	0.6	0.7	0.5	0.4	0.4	0.6
Length of posterior lobe	1.2	1.7	1.3	1.2	0.9	1.2
Width of glabella at base	1.2	1.3	1.2	0.9	0.9	0.9
<u>Pygidium</u>						
Length of pygidium			<u>KHNF-25</u>	<u>KHNF-2</u>	<u>KHNF-38</u>	
Width of pygidium			2.1	1.5	1.5	
Length of axis			2.5	1.7	1.2	
Frontal width of axis			1.7	1.2	1.2	
Width of axis at mid length			1.5	0.6	0.9	
			1.7	0.6	0.9	

Order	:	PTYCHOPARIIDA	Swinerton, 1915
Suborder	:	PTYCHOPARIINA	Richter, 1933
Superfamily	:	EMMRICHELLACEA	Kobayashi, 1935
Family	:	INOUYIIDAE	Chang, 1963
Genus	:	<u>CYCLOLORENZELLA</u>	Kobayashi, 1960

Cyclolorenzella sp.  
( Plate A, 12 - 14 )

Cyclolorenzella sp. Jell, 1986, p. 490,  
Fig. 2c-2e

Cyclolorenzella sp. Whittington, 1986,  
p. 175, Pl. 18; Fig. 2, 3.

Material :

Four cranidia in poor state of preservation in blocks of green shale.

Description :

Cranidium fairly convex, semicircular in outline, width exceeding the total cranidial length, gently rounded at the frontal margin, glabella small, as wide as fixed cheek, truncato-conical, convex, occupying approximately 0.6 of cranidial length, tapering forward, lateral glabellar furrows obsolete, axial furrows very deep, occipital furrow strong, occipital ring wide at the centre than at the sides, posteriorly directed without occipital spine. Frontal area convex with

very faint furrows running forward from axial furrow to give faintest impression of a median boss, anterior border narrow, of uniform width, flat but upturned anteriorly, short distinct border furrow, eye ridges distinct, transverse from anterolateral corner of glabella, palpebral lobe small, situated just ahead of the glabellar mid length. Facial suture convergent ahead of eyes and divergent behind it, postero - lateral areas wide and flat.

<u>Dimensions ( in mm )</u>	<u>Specimen numbers</u>			
	<u>JAMF-41</u> <u>1</u>	<u>JMSF-22</u> <u>1</u>	<u>JMSF-29</u> <u>1</u>	<u>JMSF-35</u> <u>1</u>
Total cranidial length	4.1	6.5	5.4	8.6
Posterior cranidial width	6.9	12.7	9.8	15.2
Total glabellar length	2.7	4.9	3.2	6.2
Glabellar width at base	3.0	5.2	3.8	7.5
Sagittal width of preglabellar area	0.6	0.9	0.8	1.2
Sagittal width of anterior border	0.4	0.5	0.3	0.7
Width of the cranidium at eye lobe	4.9	7.3	6.2	10.7

Remarks :

On the basis of general outline of the cranidium, truncato-conical glabella, obsolete lateral glabellar furrows,

deep axial furrow, narrow anterior border, small eye lobes and medially elongate occipital ring the specimens can easily be assigned to genus Cyclolorenzella. The specimens correspond in all its morphological characters to Cyclolorenzella sp. described from Kashmir by Jell ( 1986 ). But whereas Jell's form is from Trahagam section, the form presently being described is found in the Magam section. The Cyclolorenzella sp. described from Zanskar in Ladakh Himalaya by Whittington ( 1986 ) is characterized by granular surface and lacking in border and in this respect in differs from this form.

However, this form does not match with any of the known species of this genus. Cyclolorenzella quadrata (Kobayashi, 1935 ) differs in possessing a subquadrate cranidium, posteriorly placed eyes and fixed cheek less wide than the Kashmir form. With C. regularis ( Walcott, 1906 ) and C. yentaiensis ( Chu, 1959 ) from China the resemblance is less close, as these forms are characterised by an unusual swelling in the frontal limb and a short pointed, posteriorly directed occipital spine.

As the material comprises poorly preserved specimens, a new specific name cannot be assigned to this form.

Horizon and locality :

The form is being reported from the Damesella Zone of the Magam section ( Trahagam Formation ) from the Magam side.

Superfamily : DIKELOCEPHALACEA Miller, 1889,  
 Family : DIKELOCEPHALIDAE Miller, 1889  
 Genus : WALCOTTASPIS Ulrich & Resser, 1930

Walcottaspis sp.  
 ( Plate - A, 15 & 16 )

Material :

Two cranidia in a poor state of preservation in blocks of dark green shale.

Description :

Cranidium subquadrate, gently arched at the front, nearly flat, width slightly more than its length. Glabella small, quadrate, gently rounded in front, occupies about sixty per cent of cranidia l length, nearly as wide as long and almost of uniform width. Axial furrow very shallow. Lateral glabellar furrow obsolete. Frontal area very wide having a length about one- third that of cranidium.

Preglabellar furrow shallow, straight, preglabellar area wide, downsloping from the front of the glabella, anterior border narrow flat, of uniform width, no line of demarcation (anterior border furrow) exists in the frontal area to separate the anterior border and preglabellar field. Eye ridges narrow, faint, starting from the anterior end of glabella, eyes of medium size situated near the glabellar mid length, palpebral area of fixigene about 0.4 the glabellar width. Occipital furrow shallow, faint, occipital ring well developed, with gently rounded surface of uniform width. Surface of the cranium finely granulose.

Posterior limb narrow, straight, length nearly equal to posterior width of the glabella. Facial suture divergent in front of eye lobes but turn gently and extend in a broad curve inward after reaching border and cut anterior margin near axial line of cranium, posterior course diverges behind eye lobes and continues in straight line till it reaches the posterior limb.

<u>Dimensions</u> : ( in mm )	<u>Specimen numbers</u>	
	<u>JMF-174</u> <u>1</u>	<u>JAMF - 11</u> <u>1</u>
Total cranidial length	6.5	5.6
Posterior cranidial width	9.6	6.7
Total glabellar length	4.5	3.2
Glabellar width at base	3.9	3.0
Frontal area	1.9	1.5
Width of cranidia at eye	7.6	6.5

Remarks :

The specimens correspond to Walcottaspis in cranidial morphological characters especially in the glabellar details, the outline of glabella, eye ridges and frontal area. However, it does not match with any of the known species of this genus. Walcottaspis vanhornei (Walcott, 1925) the genotype differs in having comparatively larger eye, oblique eye ridges and curvature of the facial suture. Because of very poor preservation and scarcity of material, it cannot be assigned to a new species.

The specimens also show some resemblance to Haniwa transversa (present work) from the same horizon and locality from Kashmir. But H. transversa differs in having a cranium

which is slightly more in length than in width, glabella truncato-tapering, glabellar width more at the posterior end than at the front and occipital ring gently curved posteriorly.

Horizon and locality :

This form is collected from Damesella Zone from Kupwara district in north - western Kashmir.

Family - PTEROCEPHALIIDAE Kobayashi, 1935  
Genus - AMURTICEPHALUS nov.

Etymology :

The name is based on the featureless cranidium. "Amurti" in Sanskrit means featureless, cephalus = cephalon.

General diagnosis :

Cranidium elongated , weakly convex, gently rounded to almost straight at the front, length more than its width, glabellar length about double its width and nearly three - fourth the total cranial length, glabella tapering with a faint median longitudinal furrow, anterior border furrow lacking, preglabellar and axial furrow shallow and very faint, narrow eye lobes with medium size eye , posterior limb narrow, almost straight and blunt at the end. Thorax and pygidium unknown.

Discussion :

The genus does not match in totality with any of the known genera on the basis of distinctive characters as discussed in the generic diagnosis. The form with which it shows close affinities is Blandicephalus Palmer ( 1954 ). The similarity is in having a featureless cranidium, length being more than width, glabella tapering forward with a median longitudinal furrow, broad preglabellar area and anterior border, which is gently arched at the front. However, Amurticephalus is quite distinctive in possessing a cranidium which is gently rounded to almost straight anteriorly, glabellar length slightly more than double its width and three -fourth the total cranidial length, while in Blandicephalus the glabellar length is almost equal to its width and about half the total cranidial length. The genus also differs in having smaller eye lobes, anterior border and preglabellar area less wide than in Blandicephalus, posterior limbs almost straight and nearly blunt at the end, whereas in Blandicephalus the posterior limbs are distinctly curved and sharply pointed.

Amurticephalus elongatus gen. et sp. nov.

( Plate A, 11, 17-20 )

Etymology :

The specific name is based on elongated nature of cranidium.

Material :

Fifteen cranidia in poor state of preservation in blocks of greenish brown sandy shale. The species is known from cranidia only.

Diagnosis :

Same as for the genus.

Description :

Cranidium gently rounded to almost straight anteriorly, weakly convex, tapering forward, distinctly elongate, total cranidial length being one and a half time more than the maximum width. Glabella subquadrate in shape, twice as long as its posterior width, parallel sided, tapered forward, gently curved anteriorly, weakly convex with a faint median longitudinal glabellar ridge. Preglabellar furrow very faint, nearly straight, axial furrow shallow, faint, three pairs of weakly developed

faint to obsolete lateral glabellar furrows, preglabellar area broad, gently downsloping from the front of the glabella, axial length of preglabellar area more than double the axial length of anterior border, anterior border wide, flat, border furrow absent and separated from preglabellar area by a slight break in slope. Occipital furrow shallow, faint ; occipital ring faint and of uniform width. Fixed cheek gently downsloping from dorsal furrow, width including palpebral lobes about one half the maximum width of glabella. Eye ridges narrow, faint to obsolete, nearly straight with narrow eye lobes situated at the glabellar mid length.

Posterior limbs narrow, almost straight, blunt at the end, length usually distinctly less than greatest width of glabella, marginal furrow shallow. Facial suture divergent in front of palpebral lobes but turn sharply and extend in a broad curve inward after reaching border and cut anterior margin near axial line of cranidium. Posterior course of facial suture diverges widely behind eye lobes and continues in a straight line until it crosses the marginal furrow.

Dimensions : ( in mm ) see page -103

Remarks :

Amurticephalus elongatus shows some resemblance to Haniwa transversa from the same stratigraphic horizon in Kashmir

Specimen numbers

	JAMF <sub>1</sub> 59a	JAMF <sub>1</sub> 59b (Holo type)	JAMF <sub>1</sub> 12	JAMF <sub>1</sub> 36	JAMF <sub>1</sub> 171	ARKF-2a	ARKF-2b
Maximum cranial length	14.0	11.0	13.0	8.5	10.5	10.2	10.6
Posterior cranial width	11.0	8.0	10.5	7.0	8.2	8.0	9.0
Maximum glabellar length	10.8	7.4	10.2	6.2	7.0	6.8	7.2
Glabellar width at base	5.2	3.6	4.9	3.0	3.4	3.0	3.5
Glabellar area (sagittal width )	2.5	1.9	2.3	1.4	1.7	1.5	1.8
Sagittal width of anterior border	1.0	0.8	1.1	0.6	0.7	0.6	0.9
Cranial width at eye lobes	11.5	10.0	11.6	7.5	9.0	8.5	9.4

in having a forwardly tapering glabella, faint lateral glabellar furrows and also in the general outline of the cranidium but in H. transversa the cranidium is not elongated, preglabellar and axial furrows are well impressed, eyes are large, glabellar length and width of nearly equal size and in these characters it differs from A. elongatus.

Horizon and locality :

The form has been collected from Damesella Zone of Trahagam Formation, in the Magam section at Jagarpura water point.

Genus : PEDINOCEPHALUS Ivshin, 1956

Pedinocephalus kashmirensis sp. nov.

( Plate A, 21-26 )

Etymology :

The name is based on the occurrence of this typical form from the Cambrian rocks of Kashmir.

Material :

Fifteen cranidia in a poor state of preservation in blocks of green shale.

Diagnostic characters :

Cranidium gently curved to almost straight anteriorly, weakly convex, tapering forward, glabella truncato-tapering with its width at the front nearly two - third its width at the base, three pairs of faint lateral glabellar furrows. Anterior border narrow, of uniform width, gently raised because of which it is differentiated from the flat preglabellar area, which is slightly more than double the sagittal width of the anterior border, distinct eye ridges with medium size, crescentic shaped eye . Occipital ring broad in the middle and tapers towards the sides.

Thorax and pygidium unknown.

Description :

Cranidium gently curved to almost straight anteriorly, length nearly equal or slightly more than the posterior cranial width, weakly convex, gently tapering forward. Glabella truncato- tapering with subtrapezoidal outline, weakly convex with length nearly equal to its width at the base, the width of the glabella at the front is nearly two-third its width at the

base and it covers nearly sixty per cent of the total cranial length, glabella with a faint median keel. Three pairs of very faint lateral glabellar furrows. Anterior border very shallow, almost straight to gently curved, axial furrow distinct. The frontal area consists of a wide, flat preglabellar area which slopes slightly to the front and forward, preglabellar area nearly twice the width of the anterior border, anterior border furrow very faint to nearly obsolete, border very narrow, of uniform width, gently curved to straight anteriorly. Eye ridges distinct starting from just near the anterior end of the glabella, then gently curving backward, eye of medium size, crescent - shaped and situated at the glabellar mid length. Occipital furrow shallow, moderately wide and somewhat grooved. Occipital ring broad in the middle, posteriorly projected and tapers towards the sides. Posterior border narrow, prominent and nearly straight. Fixigenae flat and almost horizontal, comprise nearly half the glabellar width measured along the middle. The part that forms the continuation of the cheeks behind the glabella slope gently towards the posterior border furrow.

Facial suture with anterior branches long which diverge from the eyes to the front. After intersecting the border they turn inward, posterior branches run obliquely from the eyes towards the sides and are then deflected backwards and cross the posterior border at places separating it from the occipital ring at a distance equal to three-fourth the glabellar width at base.

Dimensions ( in mm ) See page - 109

Remarks :

The specimen compare with Pedinocephalus in truncato-tapering glabella, with median keel, faint lateral glabellar furrows, distinct eye ridges, medium size eye, situated at the centre of glabella and in the outline of the facial suture, however, it does not match with the other known species of this genus. P. bublichenkoi Ivshin ( 1962 ), the genotype differs in having a curved anterior border furrow, anterior border more wide at the centre than at the sides and a large eye. P. bykovaе Ivshin (op.cit.) differs in having a cranidium with a complete arcuate anterior border, general outline of the cranidium and a glabella which is nearly of uniform width. P. Kasachstanensis Ivshin (op.cit.) differs in the pattern of anterior border, in the outline of the facial

suture and also in the ratio of anterior border to preglabellar area which is 2:3 in P. Kasachstanensis but in the Kashmir form the preglabellar area is slightly more than double the anterior border. With P. simplex Ivshin ( op. cit. ) the resemblance is less close because it has a preglabellar area which is one and a half times more than the anterior border, lacks lateral glabellar furrows, has narrow occipital furrow and ring. It also differs in the general pattern of the anterior border and border furrow.

This form does show some resemblance to Haniwa transversa, presently being described from the same horizon from Kashmir, especially in having a nearly flat cranidium, truncato-tapering glabella which is straight at the front but H. transversa is characterized by obsolete eye ridges, lack of anterior border furrow and glabella of uniform width. With A. murticephalus elongatus the resemblance is less close as A. elongatus has a very elongated cranidium, whose length is nearly double its width, a very long glabella and obsolete eye ridges.

Horizon :

The form is collected from the Damesella Zone of Trahagam Formation in Magam Section, near Jagarpura water point.

Dimensions: ( in mm )

	<u>Specimen numbers</u>									
	JAMF <sub>1</sub> 111	JAMF <sub>1</sub> 63	JAMF <sub>1</sub> 59	JAMS 1	JMSF <sub>1</sub> 41	JMSF <sub>1</sub> 46	JMSF <sub>1</sub> 70	JMSF <sub>1</sub> 72	JMSF <sub>1</sub> 70	JMSF <sub>1</sub> 72
Maximum cranial length	4.2	10.5	7.1	7.5	6.5	5.9	4.8	5.6	4.8	5.6
Posterior cranial width	5.4	13.8	8.5	9.2	7.9	6.8	5.6	6.2	5.6	6.2
Maximum glabellar length	2.9	7.6	5.2	4.8	3.8	3.4	3.0	3.2	3.0	3.2
Glabellar width at base	3.0	8.0	6.1	5.2	4.2	4.1	3.5	3.4	3.5	3.4
Sagittal width of preglabellar area	0.8	1.9	1.2	1.2	1.0	0.9	0.8	0.9	0.8	0.9
Sagittal width of anterior border	0.4	1.0	0.6	0.7	0.5	0.4	0.3	0.3	0.3	0.3
Cranial width at eye lobes	3.5	9.6	6.2	6.8	5.4	4.9	3.9	4.1	3.9	4.1

Superfamily : OLENACEA Burmeister, 1843  
Family : OLENIDAE Burmeister, 1843  
Subfamily : OLENINAE Burmeister, 1843  
Genus : OLENUS Dalman, 1827

Olenus haimantensis Reed

( Plate B, 1-9 )

Olenus ? haimantensis Reed, 1910, p. 40, pl. v,  
Fig. 14 - 18.

Hundwarella haimantensis Kobayashi,  
1967, p. 487.

Material :

Fifteen well preserved complete exoskeletons and sixteen cranidia and fragments of cranidia in a poor state of preservation, in blocks of dark grey shales.

Description :

Exoskeleton oval to elongate. Cephalon broadly semicircular. Cranidium moderately convex. Anterior border narrow, weakly convex, almost straight, about as wide as the preglabellar area, border furrow shallow, distinct. Preglabellar area very narrow, convex, of uniform width.

Glabella broad, parallel sided, oblong to subtrapezoidal in shape with anterior and gently rounded or truncate, surface moderately convex, length of the glabella nearly equal to its width. Three pairs of discontinuous lateral glabellar furrows, of which the first (counting from anterior) is short, almost straight, less distinct, nearly obscure, the second glabellar furrow is slightly longer than the first, distinct, gently oblique nearly horizontal, the third furrow very prominent, longest, strongly oblique backwards, stopping just short of occipital ring. Eye ridges distinct, nearly straight, starting from just near the second glabellar furrow, eye of small size situated at the glabellar mid length between second and third glabellar furrow. Occipital ring nearly of uniform width almost straight, occipital furrow distinct, some specimens show a faint trace of an occipital node at the middle of the ring. Fixed check gently convex about two-third the width of glabella at eyes and about three fourth its width at base. Facial suture with anterior branches cutting margins of cranidium at about two times the width of the glabella, curving back and outwards in a convex arc to eyes but scarcely bending in, posterior

branches curving back simply to cut posterior border at about  $45^{\circ}$  angle, nearly two-third the way out to genal angle and not further out than anterior branches on anterior border. Free cheek elongate. Lateral border narrow and confluent with straight genal spine. Posterior border narrow and short, forming slightly obtuse inner spine angle, marginal furrow well impressed.

Thorax of 12-14 segments, broad, axis convex less than one third the total width of thorax, gradually tapering backward, axial rings with faint lateral swellings. Pleurae horizontal outwards upto fulcrum beyond which they are gently curved back to end in a short, free, pointed, posteriorly directed spine, surface marked by a narrow, deep diagonal furrow.

Pygidium semicircular to subtriangular, nearly one fourth length of thorax with simple narrow flattened border. Anterior width of the pygidium nearly two and half times more than its length. Axis slightly conical, less than one third width of pygidium, obtusely pointed, nearly extending to the marginal furrow, composed of 4-6 rings; lateral lobes gently convex consist of 5 pairs of pleurae. Each pleura with fine medium furrow and usually traceable across flattened border. Inter-pleural furrows strong.

Dimensions : ( in mm ) see page - 114

Remarks :

The specimens correspond to Olenus ? haimantensis Reed in all its morphological details. Reed ( 1910 ) had doubtfully assigned this form to genus Olenus taking into consideration the revised description of genus Olenus by Lake (1908 ). He remarked that subquadrate shape of the glabella, the transverse shape of the cephalon, narrow fixed cheek, position of eye ridges, characters of thorax and number of segments in the pygidium recalls O. attenuatus Boeck (1827), but the eyes in the latter are further forward, smaller in size, anterior border narrow and anterior branches of facial suture are subparallel, instead bending outwards in a convex curve in front of the eyes. Reed also compared it with Bathyriscus ? stoliczkai and found that the course of facial suture and shape of thoracic pleurae were sufficient to remove it from B. ? stoliczkai.

Kobayashi (1967) stated that Olenus ? haimantensis from Spiti cannot be assigned to Olenus on the basis of

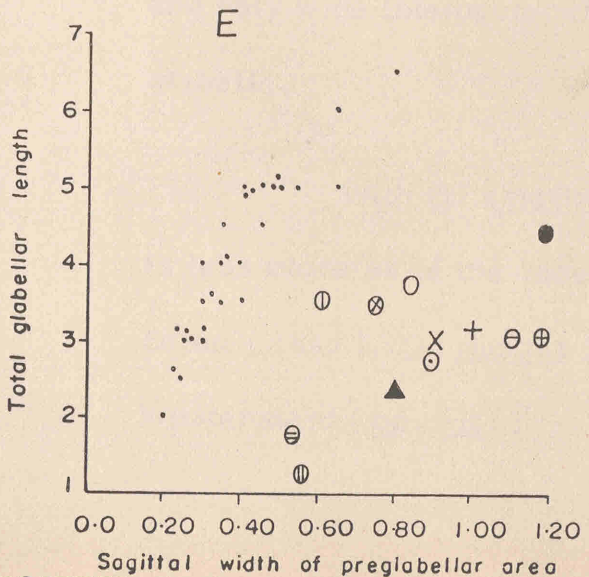
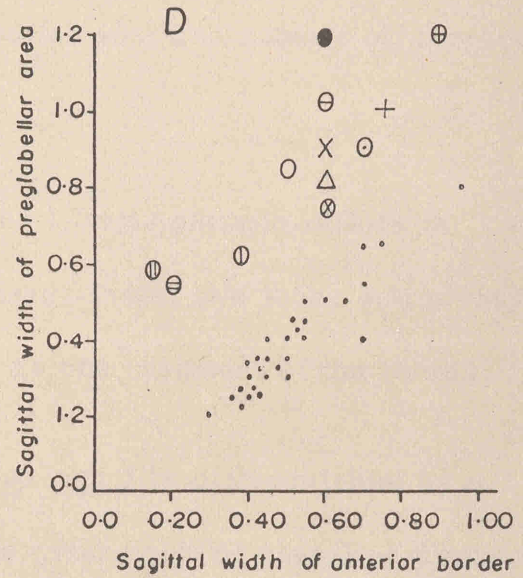
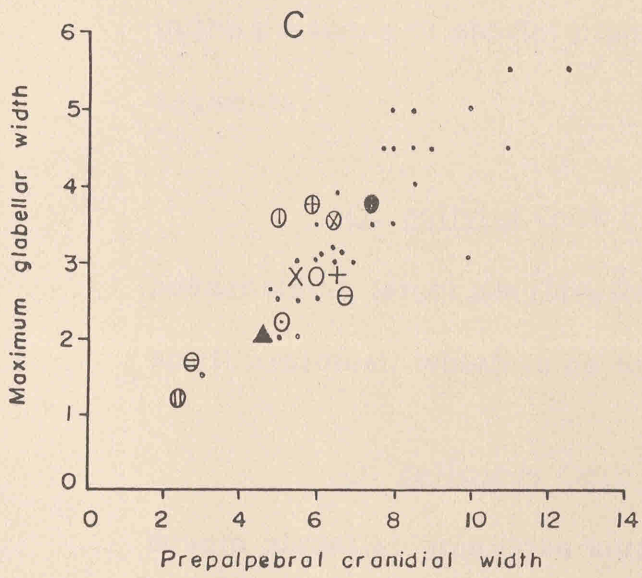
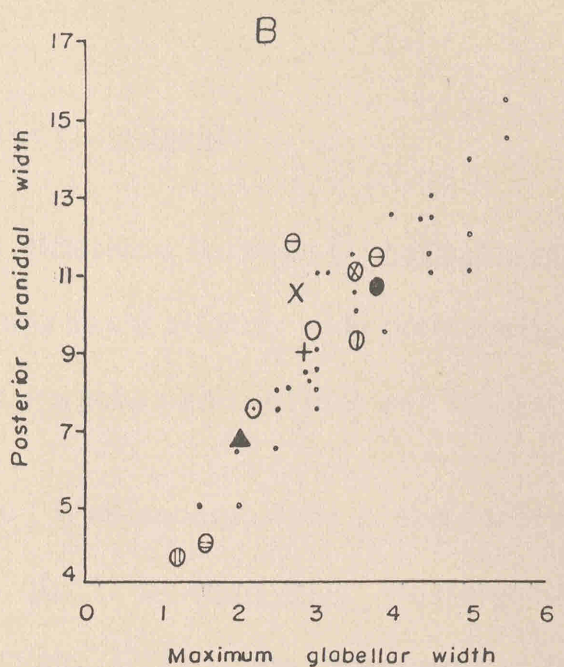
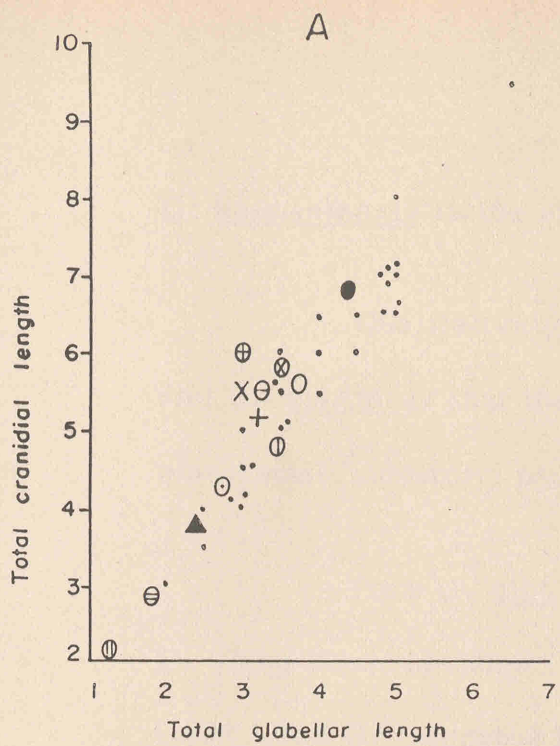
	<u>Specimen numbers</u>				
	<u>AR-1</u>	<u>AS-5</u>	<u>ARP-50</u>	<u>ARP-46</u>	<u>ARP-70</u>
Length of complete exoskeleton	9.5	-	10.5	7.5	13.0
Length of cranium	3.0	6.5	3.5	2.5	5.0
Posterior cranial width	6.0	11.0	7.0	6.0	9.5
Length of glabella	2.5	4.5	2.8	2.0	3.5
Width of glabella at base	2.3	4.3	2.5	2.0	3.0
Preglabellar field (length )	0.3	1.0	0.4	0.3	1.2
Sagittal width anterior border	0.2	0.8	0.3	0.2	0.8
Length of thorax	4.5	-	5.0	4.0	6.0
Length of pygidium	2.0	-	2.5	1.0	2.0
Anterior width of pygidium	3.5	-	4.5	3.0	4.0
Length of axis of pygidium	1.0	-	1.8	0.5	1.0
Frontal width of pygidial axis	1.5	-	2.0	0.8	1.4

revision of this genus by Henningsmoen (1957) and had given it a generic shift from Olenus ? haimantensis to Hundwarella haimantensis. He also suggested that Bathyriscus ? stoliczkai and Dicellocephalus ? interpres from the same horizon and locality are the axially and laterally compressed form of same species synonymous with Hundwarella haimantensis. Olenus haimantensis, however, is a distinctive form in having a subtrapezoidal glabella, raised anterior border, almost straight eye ridges, smaller eye, single posterior-most lateral glabellar furrow and thus cannot be grouped with Hundwarella. Bathyriscus ? stoliczkai and Dicellocephalus ? interpres are quite different from O. haimantensis but are no doubt axially and laterally compressed forms of a single species congeneric with Hundwarella and are, therefore, referred as H. interpres ( present work ).

Assigning of this taxon to Olenus by Reed is undoubted as has been discussed by the author ( Kishore, 1982 ), both on the basis of qualitative and quantitative characters, where five paired sets of seven measured dimensions were taken for statistical treatment and the result thus obtained show that the coefficient of correlation for the

population of O. haimantensis from Spiti is highly significant and the standard error of estimate negligible, which is indicative that the population has a quantitative basis as well, for being included in a single species and, therefore, corroborates the qualitative description. The population obviously has a genetic relationship, which can be easily seen from the scatter diagram ( Fig. 10 ).

The difference between O. haimantensis and other species of Olenus is graphically exhibited in the scatter diagram ( Fig. 10 ), in which the measured dimension of Spiti form has been plotted alongwith other known species of this genus. It is evident from the scatter diagram that in some dimensional characters many species are generally identical as is indicated in Fig. 10 A, B & C. However, whenever, the sagittal width of the prelabellar area is plotted against any other parameter, O. haimantensis stands apart from all other species as indicated in Fig. 10 D&E. The sagittal width of the prelabellar area, therefore, constitutes the most important bases of distinction of this species from other forms. In this respect the taxon showing closest affinities to



Symbols	Species
•	<i>Olenus haimantensis</i>
▲	<i>O. gibbosus</i>
●	<i>O. alpha</i>
○	<i>O. rotundatus</i>
⊙	<i>O. scanicus</i>
+	<i>O. dentatus</i>
X	<i>O. attenuatus</i>
○	<i>O. wahlenbergi</i>
⊕	<i>O. truncatus</i>
⊖	<i>O. transversus</i>
⊖	<i>O. wilsoni</i>
⊖	<i>O. ogilviei</i>
⊖	<i>O. delicatus</i>

SCATTER DIAGRAMS OF THE DIMENSIONAL PARAMETERS OF SPECIES OF *Olenus*

Q. haimantensis is the species Q. wilsoni.

Qualitatively the difference between Q. haimantensis and Q. wilsoni is that the latter has a slightly wide preglabellar area, small anteriorly placed eye lobes and oblique eye ridges.

From Q. gibbosus ( Wahlenberg, 1821 ), the genotype, Q. alpha Henningsmoen ( op. cit. ), Q. transversa Westergaard (1922 ) and Q. truncatus Brunnich (1781 ), the specimens differ in the presence of shorter preglabellar area and number of thoracic segments.

Q. ogilviei Opik ( 1963 ) from Australia differs in possessing a larger preglabellar area, larger eye lobes and a very small pygidium, which is as long as one segment of the thorax.

Q. delicatus Opik ( op. cit. ) is distinguished by a square glabella, granulose surface, four pairs of glabellar furrows and very wide interocular cheek which is as wide as half the glabella.

With Q. asiaticus Kobayashi ( 1944 ) the resemblance is less close as is the case with Q. cataractes and Q. micrurus Salter ( 1849 ), Q. mundus Lake (1908 ), and Q. rotundatus Westergaard ( op. cit. )

Horizon and locality :

All the specimens have been obtained from dark grey shales of Olenus Zone from Thango section of Parahio Valley, Spiti.

Superfamily : ANOMOCARACEA Poulsen, 1927  
Family : ANOMOCARIDAE Poulsen, 1927  
Genus : HANIWA Kobayashi, 1933

Haniwa transversa sp. nov.

(Plate B, 10-15 )

Dikelocephalites flabelliformis Sudan, 1982,

p. 175, pl. 11, g, j, m.

Etymology :

The name is based on the transverse nature of cranidium and glabella at front.

Material :

Twenty six cranidia in a fair state of preservation in blocks of greenish shale.

Diagnosis :

Cranidium flat, parallel sided, tapering forward, length slightly more than its posterior width, straight at the front.

Glabella tapering to truncato-tapering, length almost equal to its maximum width or slightly more transverse anteriorly.

Frontal area quadrate, wide, anterior border furrow lacking, preglabellar and axial furrow shallow and faint, nearly obsolete eye ridges, medium size, eye lobes with nearly semicircular eye, posterior limb straight and narrow. Occipital ring gently curved posteriorly at the centre.

Thorax and pygidium unknown.

Description :

Cranidium subquadrate, straight at the front, tapering forward, flat, length slightly more than its posterior width. Glabella tapering to truncato - tapering downsloping forward, weakly convex to flat, length almost equal or slightly more than the maximum width of glabella, narrow and straight at the front, then widening down towards the posterior, glabella having maximum width at its posterior end and occupies about two-third cranial length, axial furrows well impressed. Three pairs of faint lateral glabellar furrows. Frontal area depressed with length about one-third that of cranidium. Preglabellar furrow faint, straight, preglabellar area wide, downsloping from the front of the glabella, anterior border furrow lacking, so

preglabellar area and border cannot be differentiated. Eye ridges obsolete, eye of medium size, nearly semicircular, situated near the glabellar mid length. Occipital furrow shallow faint. Occipital ring well developed, gently curved posteriorly at the centre, width more at the centre than at the sides.

From the front end of glabella fixed cheek gently downsloping, width at the palpebral lobe about one half maximum width of glabella.

Posterior limb narrow, straight, length less than the maximum width of glabella, marginal furrow absent. Facial suture divergent in front of eye lobes but turns sharply and extend in a broad curve inward after reaching the border and cuts anterior margin near axial line of cranium. Posterior course of facial suture diverges widely behind eye lobes and continues in straight line till it reaches the posterior limb.

Dimensions : ( in mm ) see page - 124

Remarks :

Sudan ( 1982 ) referred this form from Kashmir to Dikelocephalites flabelliformis described by Sun (1924 ) from

China, on the basis of cranidial outline, glabellar details, width of fixigenae with respect to the width of glabella and wide frontal area. Dikelocephalites has some very peculiar characters viz., very broad frontal area, quadrate glabella, presence of two or three pairs of lateral glabellar furrows of which the posterior most is very characteristic and also parallel imbricating fine lines in the frontal area and very long and strap like posterior limb of cranidium. Therefore, the Kashmir form cannot be assigned to genus Dikelocephalites.

The specimens correspond to Haniwa Kobayashi (1933), on the basis of a flat, parallel sided cranidium, which is slightly more in length than its posterior width, truncato-tapering glabella, semicircular palpebral lobes, wide frontal area with its length about one third the length of cranidium and facial suture slightly divergent anterior to the eyes.

However, the Kashmir form does not match with any of the known species of the genus Haniwa. H. sosanensis Kobayashi (1933), the genotype differs in having large eye lobes, two pairs of distinct lateral glabellar furrows and an occipital ring which is nearly straight and of uniform width.

H. convexa Kobayashi (1935) differs in the shape of cranidium which is moderately convex, oblong glabella

which is convex and elevated above the cheeks, lateral glabellar furrows being represented by three pairs of pits located inside the dorsal furrow, larger eye lobes, transverse occipital ring with strong occipital furrows.

H. conica Kobayashi ( 1935 ) show some resemblance with the Kashmir form especially in the shape of glabella which is truncato-conical but H. conica has a concave preglabellar area, with narrow and poorly defined anterior border, large palpebral lobes close to glabella and in these characters it is distinguishable from Kashmir form.

H. oblongata Kobayashi ( op. cit. ) matches in having an occipital lobe which is gently convex backward, obscure glabellar furrow, median palpebral lobe. But H. oblongata has a characteristic glabella which is roundly oblong, broadest in the middle, well defined by dorsal furrows, the palpebral lobe connected with glabella by a broad semi-elliptical eye band and hence is quite distinct from H. transversa.

H. transversa also shows some resemblance to genus Aphelaspis Resser ( 1935 ) in having a flat cranium which is slightly more in length than its posterior width, forward

tapering glabella, wide frontal area, wide preglabellar furrow, dorsal furrow shallow and medium size eye but in Aphelaspis the anterior border is easily differentiated from the preglabellar area by a shallow preglabellar furrow, the cranidium and glabella strongly rounded anteriorly and in these characters it is easily distinguishable from Kashmir form.

H. transversa shows some resemblance to Shirakiella Kobayashi ( 1935 ), especially in the truncato-conical shape of glabella, lacking in glabellar furrows, transversely subquadrate frontal area without any demarcation of anterior border and medium sized eye. But the latter is easily distinguishable by a trapezoidal cranidium, elevated glabella above the flat cheeks, convex frontal area, palpebral lobes being located close to glabella and facial suture nearly parallel in front of the eyes.

Horizon and locality :

This form has been collected from the Jagarpura water point in the Magam section and faunistically lies in the Damesella Zone.

Specimen numbers

	JAMF <sub>1</sub> 171 (Holo type)	JAMS-1 a	JAMS-1 b	JAMS-1 c	JAMF <sub>1</sub> 171	JAMF <sub>1</sub> a	JAMF-57 b	JAMS <sub>1</sub> d
Maximum cranial length	12.0	10.0	8.5	8.6	10.5	10.4	8.7	10.2
Posterior cranial width	11.5	9.2	7.8	8.0	9.3	9.6	7.8	8.8
Maximum glabellar length	8.5	7.0	6.0	6.2	7.5	6.5	6.2	6.0
Glabellar width at base	8.2	6.8	5.6	6.0	7.0	5.8	5.7	5.6
Frontal area	4.0	3.6	3.2	2.9	3.8	3.5	3.0	3.5
Width of cranium at eye lobes	10.7	8.6	7.2	7.5	8.7	9.0	7.0	8.5

Superfamily : ASAPHISCACEA Raymond, 1924  
Family : ASAPHISCIDAE Raymond, 1924  
Subfamily : ASAPHISCINAE Raymond, 1924  
Genus : ANOMOCARELLA Walcott, 1906

? Anomocarella sp.

(Plate B, 16 )

Material :

A single cranidium in tolerable state of preservation,  
in a block of dark grey shale.

Description :

Cranidium, elongated, subquadrate in outline,  
moderately convex, tapering anteriorly, slightly more in length  
than the posterior cranidial width. Anterior border narrow,  
moderately flat, of uniform width, gently arched at the front.  
Width of the anterior border nearly same as that of prelabellar  
area. Preglabellar area narrow, of uniform width, slightly  
depressed. Glabella raised, convex, almost parallel sided,  
moderately tapering anteriorly with its front rounded, its central  
part sharply raised forming a median ridge, it occupies about  
eighty percent of the cranidial length, glabellar length is slightly

more than twice the width of the glabella at base. Lateral glabellar furrows absent, axial furrow narrow, well impressed. Occipital furrow shallow, nearly straight, occipital ring wider at centre and moderately arched backward. Eye ridges nearly obsolete, eye small and situated opposite the glabellar mid length. Fixed cheek narrow, its maximum width being slightly less than the total cranidial length, gently convex, upsloping but not raised upto the level of glabella.

Dimensions : ( in mm )

Specimen  
number  
AKP 21

Total cranidial length	5.2
Posterior cranidial width	4.5
Total glabellar length	3.0
Width of the glabella at base	1.3
Preglabellar area	0.9
Anterior border	0.8
Width of cranidium at eye lobes	4.0

Remarks :

The specimen correspond to genus Anomocarella in all its cranidial morphological details viz., flat anterior border,

depressed preglabellar field and absence of lateral glabellar furrows but it does not match with other known species of Anomocarella. A. chinensis the type species differs in the presence of a posterior projection of the anterior border in the middle and larger eye lobes.

Resser and Endo ( 1937 ) had emphasized the posterior projection of the anterior border in the centre as the most distinctive character of genus Anomocarella. Kobayashi (1962) remarked that anterior border projection is, however, not persistent, but its strength varies so greatly even within a species that Walcott has included the forms with and without the projection in his Anomocarella chinensis.

The specimen shows some resemblance to genus Kaninella Kobayashi ( 1938 ) especially in very narrow fixigenae and shorter palpebral lobes but Kaninella has a broader and slightly shorter glabella. In fact the specimen can be assigned to a new genus which can be placed between Anomocarella and Kaninella. However, as the material consists of a single specimen so it cannot be assigned to a new genus. Therefore, it has been placed doubtfully in Anomocarella.

Horizon and locality :

The specimen has been collected from Olenus Zone,  
Parahio valley Spiti.

Genus : HUNDWARELLA Reed, 1934

Hundwarella Reed, 1934

Irania King, 1937

Hundwarella Kobayashi, 1944, 1962

Iranoleesia King, 1955

Iranoleesia Gupta & Suneja, 1977

The genus was first described from Kashmir by Reed (1934), with Hundwarella personata as genotype.

The subsequently described genus Irania King (1937) revised to Iranoleesia King (1955) from Iran is based on the bifurcation of the rear pair of lateral glabellar furrow and its obliteration in the middle. The bifurcation is seen in Hundwarella, as well, and the various species recently found from Spiti and Kashmir (Shah et al., in press), indicate a gradation in the obliteration ranging from a completely transglabellar trace to a median obliteration of the furrow. Accordingly the genus Iranoleesia is considered synonymous with Hundwarella

(Shah & Kishore, in press), especially as in all other characters they are identical or show only minor variations at the specific level and this is further supported by the evolutionary pattern and occurrence in time of various species of this genus in Kashmir and Spiti.

Hundwarella kingi Sudan, 1982

( Plate B, 17, 18, 20, 25 )

Hundwarella kingi Sudan, 1982, p. 235,

pl. 11 ; figs. e.i.

Chuangia transversalis Sudan, 1982, p. 264

pl. 12, figs. h, o.

Material :

Eight partially preserved cranidia in blocks of greenish shale.

Description :

Cranidium sub-quadrate in outline, length less than the width, glabella low, convex, moderately tapering anteriorly with its front nearly straight and subrounded at antero-lateral ends, occupies about three-fourth the total length of cranidium, its length is nearly equal to the width at base, three pairs of lateral glabellar furrows well marked, first pair short, oblique and anteriorly directed, second pair deep, horizontal and slightly longer than the

anterior pair, third pair well impressed, horizontal, bifurcated at middle and the bifurcating branch generally oblique posteriorly, axial furrows narrow and deep; occipital furrow shallow and moderately arched. Eye ridges prominent and start obliquely outward from the base of the anterior pair of glabellar furrow, eyes of medium size situated opposite the mid length of glabella. Fixigenae upsloping but not raised to the level of glabella, palpebral area of fixigenae 0.6 the width of glabella at middle, preglabellar field short mildly sloping anteriorly, anterior border furrow shallow, anterior border raised, narrow, transverse and nearly of uniform width, facial suture cut the anterior border and turns directly backward and slightly inward towards the palpebral lobe, curves around this lobe and finally extends backward and outward to the postero-lateral extremities of the cranium.

Dimensions : ( in mm ) see page - 131

Remarks :

The specimen correspond in all its morphological details to Hundwarella kingi Sudan ( 1982 ), viz., glabella low with length nearly equal to basal width, moderately convex, slightly tapering anteriorly with faint nearly straight antero - lateral ends, three pairs of distinct lateral glabellar furrows, first pair

	Specimen numbers								
	JAMF <sub>1</sub>	JAMF <sub>1</sub>	KHNF	KHNF	KHNF	JAMF <sub>1</sub>	KHNF	KHNF	JAMF <sub>1</sub>
	21	2	84	54	73	7	38		
Maximum cranial length	8.5	12.4	10.2	11.2	5.5	8.4	10.5		
Posterior cranial width	18.0	18.6	19.0	19.5	10.0	16.5	17.4		
Total glabellar length	7.0	9.5	8.2	9.4	4.5	6.5	8.2		
Glabellar width at base	5.5	7.4	6.5	8.0	4.0	5.4	7.0		
Sagittal width of anterior border	0.5	2.0	1.0	1.5	0.5	0.8	1.2		
Sagittal width of preglabellar area	1.5	2.6	2.0	2.5	1.0	1.6	2.0		
Width of cranium at eye lobes	15.7	16.4	17.2	17.0	8.5	13.5	16.5		

(counting from the anterior end ) short, oblique and directed anteriorly, second pair deep, horizontal and slightly longer than the anterior pair, third pair well impressed, horizontal, bifurcated at middle and the bifurcating branch generally oblique posteriorly, the two opposite branches being obliterated in the middle.

The specimens assigned by Sudan to Chuangia transversalis collected from the same horizon agree in all observable characteristics with the diagnostic features of Hundwarella kingi as described by Sudan and are, therefore, considered to be synonym of Hundawarella kingi.

The Kashmir form also shows some resemblance to the species of Hundwarella presently being described from Spiti. H. rushtoni sp. nov. does match in having a narrow preglabellar area, three pairs of lateral glabellar furrows, the third pair being obliterated in the middle and nearly equal length and width of glabella but Hundwarella kingi differs in the shape of cranidium and glabella, in having a straight anterior border with glabella nearly straight at the anterior end, preglabellar area and anterior border of same width and in the pattern of the lateral glabellar furrows.

H. kingi differs from H. interpres described from Spiti in the shape of cranidium and glabella, straight and raised anterior border, glabella straight at the front and being of equal length and width.

Horizon and locality :

This form has been collected just above the Bolaspidella Zone in Magam section, on the Magam side.

Hundwarella interpres (Reed)

(Plate B, 19, 21-24, 26  
Plate C, 2, 4, 13, 15, 20)

Bathyriscus ? stoliczkai Reed, 1910; pl. V;

Figs. 5-8.

Dicellosephalus ? interpres Reed, 1910, pl. V;

Figs. 9-13.

Material :

One tolerably preserved complete exoskeleton, two partially broken exoskeletons and twelve cranidia in a poor state of preservation, in blocks of dark grey compact shale.

Description :

Exoskeleton elongate to oval, cranidium semi-circular, narrow about one-fourth as long as wide. Anterior

border gently curved at the front, flattened, of uniform width, nearly as wide as preglabellar area, preglabellar area narrow about one-fifth to one-sixth the length of glabella, gently convex. Glabella sub-cylindrical to sub-quadrate with parallel sides, nearly three-fourth the length of the cranidium, weakly convex, anteriorly subrounded, the ratio between glabellar length and its width at the base is nearly 1.5 : 1. Three pairs of lateral glabellar furrows of which the first pair is very far forward, short and straight, the second pair slightly longer, straight and half way between first and third pairs and less than half way from the front end of the glabella, the third pair longer, bigeniculate, the anterior bifurcating branch short, straight whereas the posterior branch oblique, slightly longer. Fixed cheek narrow less than half the width of glabella at eye lobes and at base nearly equal to glabellar basal width. Eye ridges distinct, oblique, starting from the level of first lateral glabellar furrow and running posteriorly towards the eyes, eye of medium size, eye lobes prominent, upturned, swollen and situated just opposite the posterior most lateral glabellar furrow, slightly below the glabellar mid length. Occipital ring simple, straight of uniform width, occipital furrow moderately strong, gently convex. Facial sutures cut anterior

margins obliquely at about three times the width of glabella apart, arch outwards in convex curve or run back subparallel to eye, directed slightly inwards, posterior branches arch out in simple curve to cut posterior margins of cranium at about  $50-60^{\circ}$  at about two-third of the distance between axial furrows and genal angles. Axial furrow deep, narrow, parallel nearly as wide as the basal glabellar width. Free cheeks elongate, lateral border narrow, confluent with a short pointed gently curved genal spine, produced back to just near the third thoracic segment. Posterior border narrow, short, forming pointed acute genal angles.

Thorax of 12 segments, narrow, elongated, tapering gently, outer half pleural lobes strongly arched down on each side. Axis strongly convex, cylindrical, rather wide, about one-third or more the total width of thorax, axial ring simple of uniform width, nearly straight. Pleurae short, broad, flattened, straight outer half sharply bent down and slightly back, ending in abruptly truncate pointed spines.

Pygidium parabolic to semicircular, with slightly concave border, indistinctly marked off from lateral lobes, margin entire, axis conical, convex, tapering very gradually to sharply pointed extremity which reaches posterior margin of pygidium, composed

of five rings. Lateral lobes composed of five complete pleurae, gently curved back, traceable nearly to margin across concave border, each with faint median furrow.

Dimensions : ( in mm ) see page 137.

Remarks :

In having a semicircular cranidium, narrow, gently curved anterior border, convex parallel sided glabella, three pairs of lateral glabellar furrows, of which the rear pair is bifid and lower bifurcating branch posteriorly directed, medium sized, eye situated just below the glabellar mid-length, oblique eye ridges, the form can be positively included in Hundwarella.

The material constitutes the topotype for Bathyriscus ? stoliczkai and Dicellocephalus ? interpres Reed ( 1910 ), which are the axially and laterally compressed forms of the same species, for which specific name interpres has been retained, because its description is based on better preserved specimens. However, these can neither be referred to Bathyriscus Meek ( 1873 ) nor can be allied to Dicellocephalus Owen ( 1852 ), which was subsequently modified to Dikelocephalus Miller

	<u>Specimen numbers</u>						
	<u>AS<sub>6</sub>F13</u>	<u>AS<sub>6</sub>F6</u>	<u>TPAF<sub>6</sub>65</u>	<u>ARP37</u>	<u>AKP45</u>	<u>ARP36</u>	<u>ARP2</u>
Length of complete exoskeleton	-	27.0	-	-	-	-	-
Total cranial length	9.2	10.5	7.0	11.2	7.8	8.0	11.2
Posterior cranial width	11.1	12.5	8.0	15.0	8.0	9.5	15.0
Total glabellar length	6.2	6.5	4.5	9.0	5.0	4.9	8.5
Glabellar width at base	4.5	5.0	2.5	5.5	4.2	3.6	5.2
Preglabellar area	1.3	2.0	1.0	1.2	0.9	0.8	1.0
Anterior border	1.0	1.5	1.2	1.3	0.9	0.8	1.2
Width of cranium at eye lobe	10.3	10.5	7.2	13.4	7.0	8.0	13.6
Length of thorax	-	13.5	-	-	-	-	-
Length of pygidium	-	3.0	-	-	-	-	-
Anterior width of pygidium	-	8.0	-	-	-	-	-
Length of axis of pygidium	-	1.5	-	-	-	-	-
Frontal width of pygidial axis	-	2.5	-	-	-	-	-

(1889 ) because of the following marked difference in their generic characters.

Bathyriscus differs in having a narrow glabella which is somewhat expanded anteriorly , upturned anterior border, absence of preglabellar area, larger eye lobes, thorax with nine segments, larger pygidium with seven axial rings.

Dikelocephalus differs in the presence of a low glabella with nearly straight front, two pairs of faint lateral glabellar furrows, wide preglabellar area, anterior and lateral border furrow obsolete to absent, posterior border furrow narrow, long, strap like, eye ridges faint, relatively large and an elliptical pygidium.

Kobayashi ( 1967 ) has mentioned Olenus ? haimantensis Reed ( 1910 ) as congeneric to Hundwarella and furthermore made Bathyriscus ? stoliczkai and Dicellocephalus ? interpres from the same stratigraphic horizon synonymous to it. However, Olenus haimantensis is a distinctive form in having a subtrapezoidal cranidium, raised anterior border, oblong glabella, rear lateral glabellar furrow discontinuous, single, eye ridges almost straight, nearly parallel or subparallel facial suture in front of eyes, fairly wide fixed cheeks with a long spine continuous with lateral border forming an obtuse inner spine angle, thorax with horizontal pleurae,

small pygidium, triangular in shape with raised border. Therefore, it neither corresponds to these specimens nor can it be referred to Hundwarella.

H. personata Reed ( 1934 ) differs in having a wide preglabellar area, in the ratio of preglabellar area and anterior border which is 2:1, thick eye ridges, larger eye lobes and the rear lateral glabellar furrow joins with another supplementary transverse furrow to enclose a central band.

Iranoleesia pisiformis and I. falconi King ( 1955 ) differ from the specimens in possessing slightly wider preglabellar area, convex anterior border, glabella of nearly equal length and width, shape of glabella and facial suture.

I. kobayashii, I. orlovi and I. pandei described from Kashmir by Gupta and Suneja ( 1977 ) differ in the presence of four pairs of lateral glabellar furrows, thick eye ridges and position of the eyes. I. rasettii differs in having a glabella of nearly equal length and width.

Hundwarella kingi differs in the shape of cranium and glabella, straight and raised anterior border, anteriorly straight

glabella, having equal length and width, more convex and elevated fixed cheek.

H. rushtoni sp. nov. from the same horizon differs in having an anterior border which is more in width than the preglabellar area, glabella of nearly equal length and width, anteriorly directed first pair of lateral glabellar furrow, an occipital ring which is more wide at the centre than at the side and posteriorly arched at the centre.

Horizon and locality :

The specimens have been collected from the same bed and horizon in Thango section of Parahio Valley, Spiti, from where Olenus haimantensis is reported.

Hundwarella rushtoni sp. nov.

( Plate C, 1, 3, 5, 7-12, 14, 16-19, 23-28 )

Etymology :

The species is named in honour of Dr. A.W.A. Rushton in recognition of his contribution to trilobite taxonomy.

Material :

One tolerably preserved complete exoskeleton and sixteen cranidia in a poor state of preservation in blocks of dark grey compact shale.

Diagnosis :

Anterior border gently curved, of uniform width, the ratio of anterior border and prelabellar area is nearly 1.7:1; glabella raised, moderately tapering anteriorly, subrounded, length of the glabella nearly same as its width, three pairs of lateral glabellar furrows, of which the anterior is small, gently directed anteriorly and the posterior one bigeniculate and bifurcating branch posteriorly directed reaching just near the occipital ring. Eyes of medium size. Occipital ring gently arched posteriorly at the middle, width being slightly more at the centre than at sides. Thorax with 12 segments. Pygidium with 5 axial rings.

Description :

Exoskeleton oval to elongate. Cranidium broadly semicircular to subquadrate in outline, moderately convex, tapering anteriorly. Anterior border narrow, weakly convex, gently curved at the front, border of uniform width, width of anterior border about 1.5 to 1.7 times more than the prelabellar area. Preglabellar area very narrow, convex tapering in front. Glabella raised, convex, moderately tapering anteriorly with its front slightly rounded, giving the glabella a subrounded shape, it occupies about three -

fourth the total length of the cranium, glabellar length is nearly equal to its width at base. Three pairs of discontinuous lateral glabellar furrows, well marked. First pair (counting from anterior to posterior) short, less distinct, slightly directed anteriorly, second pair deep, horizontal and a bit longer than the anterior pair, third pair distinct, longest, horizontal, bigeniculate at the middle, the two opposite branches being obliterated in the middle, of the two bifurcating branches the anterior one almost straight, small whereas the posterior being longer and oblique, directed posteriorly towards the occipital ring but stops just above the occipital ring. Fixed cheek gently convex, upsloping but not raised upto the level of glabella, about twice the width of the glabella at base. Eye ridges less distinct and start obliquely outward from the base of the anterior pair of glabellar furrow. Eye lobes of medium size and situated below the glabellar middle length just near the third lateral glabellar furrow. Palpebral area of fixigenae slightly less than the width of the glabella at base. Facial suture with anterior branches cutting the margins of cranium about one half to two times the width of the glabella, apart curving back and outwards in convex arc to eyes but scarcely bending in, posterior branches curving back, simply

to cut posterior border at about  $45^{\circ}$  and nearly thrice the width of glabella at base. Posterior border straight and narrow. Occipital furrow distinct, deep and slightly arched towards the posterior end at the centre. The width of the occipital ring slightly more in the centre than at the sides.

Thorax of 12 segments, broad, axis convex, less than one-third the total width of thorax, gradually tapering backward. Axial rings with faint lateral swellings. Pleurae horizontal out to fulcrum, beyond which they are gently curved back to end in short free pointed, posteriorly directed spines.

Pygidium semitriangular, nearly one-fourth the length of thorax, with simple narrow flattened border. Anterior width of the pygidium is nearly twice its length. Axis slightly conical, less than one-third the width of the pygidium, obtusely pointed, nearly extending to marginal furrow, composed of 5 rings. Lateral lobes gently convex with 5 pairs of nearly horizontal pleurae. Interpleural furrows strong.

Dimensions ( in mm ) : See page - 147

Remarks :

The specimen correspond to genus Hundwarella in

all its cranial morphological details viz., a semi-circular cranidium; moderately convex fixed cheek; three pairs of lateral glabellar furrow, of which the first pair short, anteriorly directed, second pair longer straight and third pair bigenulate in nature; short eye ridges, starting from 1st pair of lateral glabellar furrow, oblique, medium size eye. However, these differ from all the known species of Hundwarella.

With H. personata Reed ( 1934 ) the genotype, it differs in possessing a narrow preglabellar area, in the ratio of preglabellar area and anterior border, which is 2:1 in H. personata, smaller eye lobes, thin eye ridges and obliterated third pair of lateral glabellar furrow ( counting from anterior to posterior ) whereas in H. personata the third lateral glabellar furrow joins with another transverse supplementary furrow to enclose a central band.

The specimens corresponds to Iranoleesia pisiformis King ( 1955 ) in narrow eye ridges, medium sized eye and bifurcating third pair of lateral glabellar furrows but differ in the presence of narrow preglabellar area, in the ratio of preglabellar area - anterior border, gently curved anterior border,

which in I. pisiformis is considerably arched forward and in the first pair of lateral glabellar furrow being directed anteriorly whereas in I. pisiformis it is perfectly straight. From I. falconi King ( 1955 ) the specimens differ in possessing a narrow preglabellar area, in the ratio of anterior border and preglabellar area, shape of the glabella and facial suture, a smaller eye, whereas the facial suture in I. falconi is more curved just above the glabella. It has a glabella which is more in length than its width and the first pair of lateral glabellar furrow perfectly straight.

From I. kobayashii, I. orlovi and I. pandei described from Kashmir by Gupta and Suneja ( 1977 ), the specimens differ in the presence of three pairs of lateral glabellar furrows instead of four as is the case in the above mentioned species. These species also differ from Hundwarella rushtoni in the length-width ratio of the glabella, the length of the glabella being much more than its width and in having thick eye ridges.

The specimens correspond to I. rasettii Gupta and Suneja ( 1977 ) in having three pairs of lateral glabellar furrows, narrow preglabellar area, medium size eye and position of eye

lobes but differ in the ratio of anterior border and preglabellar area, width of the anterior border being about 1.5 to 1.7 times more than the width of the preglabellar area. Hundwarella rushtoni also differs in variable width of the occipital ring, the width being more at the centre than at the sides and also the occipital furrow arched posteriorly, whereas in I. rasettii the occipital ring is straight and of uniform width.

H. Kingi does match in having a narrow preglabellar area, three pairs of lateral glabellar furrows, the third pair being obliterated in the middle and nearly equal length and width of the glabella but differs from H. rushtoni, in the shape of cranidium and glabella, in having a straight anterior border with glabella nearly straight at the anterior end, preglabellar area and anterior border of same width, pattern of lateral glabellar furrows, fixed cheek more convex and elevated at the middle.

Horizon and locality :

This form has been collected from the same bed and horizon in Parahio valley Spiti from where H. interpres and Olenus haimantensis have been reported.

## Dimensions : ( in mm )

	Cranidium												
	AKP 44	TPAF <sub>6</sub> 14	ARPF <sub>6</sub> 44	S <sub>6</sub> F 84	S <sub>6</sub> F 37	AR7 (Holo- type)	ARP 88	ARP 32	ARPF <sub>6</sub> 15	SP <sub>3</sub>	S <sub>6</sub> F 29	TPAF <sub>6</sub> 34	TPAF <sub>6</sub> 64
Total cranial length	5.2	6.3	3.0	3.5	5.8	7.5	6.2	4.5	4.2	5.0	3.8	8.5	3.2
Posterior cranial width	8.7	10.5	5.1	5.4	10.2	12.8	10.6	7.4	7.0	8.0	5.8	14.2	5.8
Total glabellar length	3.8	4.2	1.8	2.3	4.5	4.9	4.2	3.2	3.0	3.8	2.5	5.9	2.0
Width of the glabella at base	3.6	3.9	1.8	2.2	4.3	4.6	4.2	3.1	3.0	3.6	2.2	5.8	1.8
Preglabellar area	0.4	0.5	0.3	0.4	0.5	0.7	0.6	0.4	0.3	0.3	0.4	1.2	0.3
Anterior border	0.6	0.8	0.5	0.7	0.8	1.0	0.8	0.7	0.6	0.5	0.6	1.0	0.5
Width of the cranidium at eye lobes	6.5	8.2	3.8	4.8	8.5	10.4	9.2	6.5	5.8	7.1	4.6	11.5	5.2

## Pygidium :

## Specimen No. AR-7

Length of pygidium	4.0
Anterior width of pygidium	10.5
Length of axis of pygidium	3.2
Frontal width of the axis	3.0

Genus : SPITELLA gen.nov.

Etymology :

The name is based on the occurrence of this typical form from Thango Section of Parahio Valley, Spiti.

Generic diagnosis :

Cranidium subtrapezoidal to subquadrate in outline, basal width more than the total cranidial length, anterior border gently raised with deep border furrow. Preglabellar area nearly twice as wide as the anterior border. Glabella conical with rounded anterior end, basal glabellar width about one and a half time more than the total glabellar length. Three pairs of lateral glabellar furrows, all being bifid, the bifurcating branches of all the furrows are obliterated in the middle. Eye ridges nearly straight, prominent, with small eyes situated at the glabellar mid length. Thorax and pygidium unknown.

Discussion:

The specimen cannot be assigned to any existing genus because of the distinctive cranidial morphological features of this form as described in the generic diagnosis. On the basis of these

distinctive characters the specimens have been assigned to a new genus even though the material is scanty.

The genera with which it shows resemblance to a certain extent are Hundwarina Parcha ( personal communication ), Apheloides Ivshin ( 1962 ), Palaedotes Opik ( 1967 ) and Perneraspis Prantl ( 1947 ).

With Hundwarina described from Kashmir it shows affinities in raised anterior border, conical glabella preglabellar area being wider than the anterior border and the presence of three pairs of lateral glabellar furrows. But it differs from Hundwarina because the latter has (i) a glabella which is nearly equal in length and width, (ii) eye ridges start from the first lateral glabellar furrow bending sharply oblique to the posterior with a crescent shaped medium size eye, situated just below the third lateral glabellar furrow, (iii) three pairs of lateral glabellar furrows of which the second and third are bifid, while the second glabellar furrow is obliterated in the middle, the third or the posterior most is transglabellar in nature forming a central triangular lobe. Occipital ring nearly straight and of uniform width.

Apheloides shows some resemblance in having a cranidium which is subtrapezoidal in outline, elevated anterior border and a moderately convex glabella which converges conically towards its anterior end, three pairs of lateral glabellar furrows prominent eye ridge with a small centrally located eye but differs in an arcuate anterior border which is more in width than the preglabellar area, length and width of glabella nearly same and only the posterior most lateral glabellar furrow being bifid in nature.

Palaeodotes resembles in having a glabella which is converging at the front, three pairs of glabellar furrow of which the posterior most is bifid and small eyes which are present at the glabellar mid length but Palaeodotes lack preglabellar area, anterior border represented by a very narrow, shallow furrow, 1st lateral glabellar furrow very forward, just behind the anterior end of the cranidium, glabellar length more than its width and in these characters it does not match with this form.

Perneraspis shows affinities in general outline of the cranidium, shape of the glabella which is wider at base and

narrow at the front, straight eye ridges and small eye situated at the glabellar middle but differs in having only two lateral glabellar furrows which are very short and preglabellar area, anterior border of nearly equal length.

Spitella barachuda gen et sp. nov.

( Plate C, 6, 21 & 22  
Plate D, 1-4 ).

Etymology :

The species is named on Barachu the local name of river Parahio in Spiti.

Material :

Eight cranidia in blocks of dark grey shale, in fair state of preservation.

Diagnosis :

Same as for the genus.

Description:

Cranidium moderately convex with subtrapezoidal to subquadrate outline, width of the cranidium at its base more than the total cranidial length. Anterior border narrow,

gently raised width slightly more in the centre than at the margins, nearly straight at the front, anterior border furrow deep, prominent. Preglabellar area narrow of uniform width, nearly twice as wide as the anterior border, tapering forward, preglabellar furrow well developed deep. Glabella conical, rounded anteriorly, side of the glabella diverging towards the posterior end, basal glabellar width about one and a half time more than the total glabellar length. Three pairs of well developed lateral glabellar furrows, of these the first one ( counting from anterior ) short, less distinct, posteriorly directed and bifid, second glabellar furrow long, distinct, bifid, posteriorly directed, third lateral glabellar furrow prominent, posteriorly directed and bifid. All the three bifurcating branches are obliterated in the middle. Axial furrow well impressed, narrow. Occipital furrow deep, gently arched backwardly, occipital ring wider at the centre and strongly arched backwardly. Eye ridges prominent, straight, starting just near the anterior end of the glabella, eye of small size and situated at the mid glabellar length between second and third lateral glabellar furrow. Fixed cheek wide, width nearly twice its

length, gently convex, upsloping but not raised upto the level of anterior border.

Dimensions : ( in mm )

	S <sub>6</sub> F-44 ( Holotype )	ARP <u>68</u>	ARP <u>74</u>	AS <u>49</u>
Maximum cranidial length	2.9	4.5	6.5	5.6
Posterior cranidial width	5.8	9.2	12.5	10.5
Total glabellar length	1.5	3.0	4.5	4.0
Width of the glabella at base	2.5	4.0	5.0	5.4
Preglabellar area	0.8	1.0	1.0	0.9
Anterior border	0.3	0.5	0.8	0.6
Width of the cranidium at eye lobes	3.7	6.0	8.5	7.0

Horizon and locality :

The specimens have been collected from the Olenus Zone in Parahio Valley Spiti.

Subfamily : BLOUNTINAE Lochman, 1944

Genus : BLOUNTIA Walcott, 1916

Blountia subangulata sp. nov.

( Plate D, 6, 7, 9 )

Etymology :

The name is based on the basis of angular border and subangular fixed cheek.

Material :

Twelve cranidia in a poor state of preservation in blocks of greenish shale.

Diagnosis :

Cranidium sub - trapezoidal, length nearly equal to its posterior width, moderately arched transversely. Glabella prominent, as wide as long, gently rounded anteriorly, three pairs of very faint lateral glabellar furrows. Frontal area with distinct angular anterior border and preglabellar area, border nearly half the sagittal width of preglabellar area, border furrow angular. Eye ridges faint with medium size eye situated just ahead of glabellar mid length and narrow fixed cheek, occipital ring narrow and of uniform width.

Thorax and pygidium unknown.

Description :

Cranidium subtrapezoidal with length nearly equal to its posterior width, moderately arched transversely and longitudinal, gently rounded anteriorly. Glabella prominent as wide (at base) as long, tapering forward and gently rounded anteriorly. Axial furrows and preglabellar furrow well impressed at sides and front. Three pairs of very faint lateral glabellar furrows. Frontal area with distinct anterior border and preglabellar area, border furrow distinct almost straight, border angular, moderately arched upward gently rounded anteriorly and is nearly half the sagittal width of the preglabellar area, preglabellar area moderate, gently convex. Eye ridges very faint to nearly obsolete, eye of medium size and situated just above glabellar middle length. Occipital furrow distinct, nearly of uniform width, occipital ring relatively short, rounded without occipital spine, occipital node absent. Posterior limbs nearly straight, its length almost equal to width of glabella at occipital furrows.

Anterior course of facial suture nearly straight until the border and then turns inward to cut the margin, about midway between antero-lateral corners of cranidium and axial line,

posterior course divergent behind the eye lobes. Fixigenae subangular, gently convex, width one half or less that of glabella.

Dimensions : ( in mm ) see page-157

Remarks :

On the basis of characteristic features viz., anterior rounded cranidium, prominent rounded glabella with shallow glabellar furrows, distinct axial, pre - glabellar and anterior border furrow, narrow, distinct border and small eyes situated anterior to preglabellar middle length, the specimens correspond to genus Blountia. However, these are easily distinguishable from all the known species of this genus.

The genus Blountia itself is divided into different subgenera viz., Blountia (Blountia) Walcott ( 1916 ), B. ( Homodictya ) Raymond ( 1937 ) and B. ( Mindycrusta ) Opik ( 1967 ), on the basis of abbreviated occipital furrow and shape of the thoracic pleural furrows. Opik ( op. cit., p. 234 ) suggested that all species whose thorax is unknown and are listed as belonging to Blountia are referable to that genus without any subgeneric designation.

Dimensions : ( in mm )

	Specimen numbers			
	JAMF <sub>1</sub> 115a	JAMF <sub>1</sub> 115b	JAMF <sub>1</sub> 115c	JAMF <sub>1</sub> 114a 114b
Total cranial length	3.5	4.6	3.8	3.6 3.2
Posterior cranial width	4.2	5.3	4.5	4.2 3.8
Total glabellar length	2.5	3.0	2.8	2.6 2.0
Glabellar width at base	2.0	2.8	2.5	2.4 1.8
Sagittal width of anterior border	0.3	0.5	0.4	0.3 0.2
Sagittal width of the preglabellar area	0.6	0.8	0.6	0.5 0.4
Width of the cranium at eye lobes	4.0	4.8	4.2	3.8 3.5

In the absence of thorax, the Kashmir form, therefore, cannot be assigned to any subgenus. The Australian species of this genus show some resemblance especially in the shape of glabella and cranidium but all the species from Australia have been placed in subgenus Mindycrusta by Opik (op. cit.). These forms are characterised by an abbreviated occipital furrow, relatively long eye lobes and rounded tips of the postero-lateral limbs and thus are easily distinguishable from the Kashmir form.

The specimens also show some resemblance to Modocia Walcott (1924) in the shape of glabella which is rounded at front, three pairs of faint to obsolete glabellar furrows and small eye but Modocia has a straight anterior border furrow, distinct eye ridges, posterior areas subtriangular and long and in these characters it is easily distinguishable from the Kashmir form.

None of the forms reported from the same horizon in Kashmir are close enough to Blountia subangulata, to necessitate a comparison because the latter is characterised by a distinct anterior border, border furrow and prominent glabella which is anteriorly rounded.

Horizon and locality :

This form has been collected from Damesella Zone in Magam section, at Jagarpura water point.

Blountia sp.  
( Plate D, 5, 8, 12, 13 )

Material :

Five cranidia in a poor state of preservation in blocks of dark green shale.

Description :

Cranidium, subtrapezoidal to nearly semicircular with length slightly less than its posterior width, gently arched anteriorly. Glabella subquadrate with truncate front, gently convex, tapering forward, sub-rounded at the antero-lateral end, length of the glabella slightly more than its maximum width, glabella a little more wide at the base than at the front. Axial and dorsal furrows well impressed. Three pairs of shallow lateral glabellar furrows. Frontal area narrow with distinct anterior border and preglabellar area. Anterior border furrow distinct, straight, border weakly convex, preglabellar area nearly of same width or slightly more than the anterior border. Eye ridges very prominent starting from the front of the glabella,

gently directed posteriorly, eye of medium size, situated just ahead of the glabellar mid length. Occipital furrow distinct, straight, occipital ring very wide at the centre than at the sides, backwardly directed with a prominent occipital node. Posterior limb straight of uniform width and its length nearly equal to the maximum width of the glabella. Fixigenae gently convex and almost parallel at side, with palpebral area same in width as glabella. Anterior course of facial suture nearly straight forward until on to border then gently curve inward to cut the margin slightly in way from the antero - lateral corners of cranidium, posterior course of facial suture nearly straight behind the eye lobes, weakly diverging near the posterior limbs.

Dimensions : ( in mm ) see page - 161

Remarks :

In having a subtrapezoidal cranidium which is gently arched at the front, subquadrate glabella with three pairs of shallow glabellar furrows, distinct border and preglabellar area and medium size eye situated just ahead of the glabellar mid length, the specimens can easily be referred to Blountia.

However, it does not match with any of the known

Dimensions : ( in mm )

Specimen numbers

	JAMF <sub>1</sub>	ARKF	JAF	JAF
	<u>44</u>	<u>3</u>	<u>36</u>	<u>18</u>
Total cranial length	7.0	7.5	9.0	8.0
Posterior cranial width	8.4	8.6	12.2	10.6
Total glabellar length	4.2	5.6	6.8	6.2
Glabellar width at base	3.5	4.5	5.4	4.8
Sagittal width of anterior border	0.5	0.5	0.8	0.7
Sagittal width of preglabellar area	2.0	2.5	3.4	3.0
Width of cranium at eye lobes	6.0	7.0	11.3	10.2

species of this genus. It differs from B. subangulata, the species presently being described from the same stratigraphic horizon in Kashmir, in having a cranidium, with length slightly less than its posterior width, prominent eye ridges, an occipital ring very wide at the centre, with width at the centre being slightly more than double its width at side and a prominent occipital node.

This form from Kashmir has a very peculiar occipital ring and a prominent occipital node which clearly differentiates it from American and Australian species of this genus.

The specimens also show some resemblance to Pedinocephalus kashmirensis from Kashmir, in the general outline of the cranidium, weakly convex glabella which is tapering forward, three pairs of faint lateral glabellar furrows and a distinct eye ridge but P. kashmirensis is characterized by a glabella whose width at the front is nearly two - third its width at the base, an anterior border which is less than one half the width of the preglabellar area, absence of occipital node, crescentic shaped eye, fixigenae with palpebral areas nearly half the width of glabella and in this respect it differs from Blountia sp. As the specimens are ill preserved and scanty, a new specific name cannot be assigned to them.

Horizon and locality :

This form has been collected from the same horizon and locality from where Blountia subangulata is being reported.

Superfamily : DAMESELLACEA Kobayashi, 1935  
 Family : DAMESELLIDAE Kobayashi, 1935  
 Subfamily : DAMESELLINAE Kobayashi, 1935  
 Genus : DAMESELLA Walcott, 1906

Damesella shergoldi Shah & Sudan, 1983

( Plate D, 10, 11, 14-22 ;

Plate E, 1-8, 11, 14, 15, 18)

Damesella shergoldi Shah & Sudan, 1983,

p. 83 - 84.

Damesella shergoldi Shah & Sudan, 1987,

p. 503-509, pl. I - II.

Material :

Two partially broken exoskeletons and about thirty cranidia and pygidia in a fair state of preservation in blocks of dark - green sandy shale.

Description :

Cranidium with width greater than the length, glabella

convex, truncato-conical, tapering anteriorly, subrounded in front, occupies about ninety per cent of the cephalic length, three pairs of lateral glabellar furrows present, anterior pair faint, short and nearly horizontal, medium pair short and deep, posterior pair highly impressed, deep and longer, both median as well as posterior pair oblique and directed backward, anterior width of the glabella slightly less than its posterior width, middle part of the glabella slightly raised forming a median ridge which runs from anterior to posterior end of the glabella; occipital ring of uniform width, curving slightly backwards at the ends and forward at the centre, rounded on top; eye ridges narrow, thread like, start oblique outward from the base of the anterior pair of glabellar furrows, eye small, swollen, situated opposite and slightly above the glabellar mid length, anterior area of fixigenae convex, raised upto the level of glabella, palpebral area of fixigenae about 0.6 the width of the glabella at middle, preglabellar field absent as the preglabellar furrow merges with the anterior border furrow which is narrow, deep and moderately arched outwardly in front of glabella; anterior border nearly transverse, depressed and stands lower than the level of glabella, the facial suture cut through the rounded frontal margin of the cephalon obliquely and then extend around backward, passing almost directly to the anterior margin of the

cephalon obliquely and then extend around backward, passing almost directly to the anterior margin of the palpebral lobe; curving around the eye lobe, then pass obliquely outward and backward, cutting the border of the cephalon a little back of the postero-lateral angle. The ornamentation of the cephalon consists of coarse scattered granules on the tumid part of the test.

Pygidium transversely semicircular in outline, having a width greater than its length; axis of pygidium convex tapering posteriorly bearing well developed five axial rings and terminal, reaching upto the base of very small posterior pair of pygidial marginal spines, pleural field slightly convex, five pleurae with deep pleural furrow running upto the base of marginal spines, six pairs of deep, well marked pygidial marginal spines, of which first, third, fourth and fifth ( counting from anterior to posterior ) are of variable lengths with a very characteristic second very small pygidial marginal spine. The sixth pair of pygidial marginal spine is also small but is relatively slightly longer than the second spine : Pygidial border narrow ; the surface of the pygidium ornamented with small, faint granules.

Dimensions : ( in mm )

	JAMF <sub>1</sub>		JMF <sub>1</sub>	Specimen numbers				
	a	b	JMF <sub>1</sub>	JAMS <sub>1</sub>	JAMF <sub>1</sub>	JAMF <sub>1</sub>		
Total cranial length	16.5	12	17	24	21	13	8	10.5
Posterior cranial width	25	18	35	39	36	22	14	16.5
Total glabellar length	14.5	10.5	13	17	16	9.5	6.5	8
Posterior glabellar width	13	9	15	15	13	7	5	6.5
Sagittal width of anterior border	1.5	1	1	2.5	2	1.5	1	1.5
Width of cranium at palpebral lobes	20	15	25	28	28	14	12	13
Thorax	-	-	-	38	-	-	-	-
<u>Pygidium</u>	JAMF <sub>1</sub>	JAMF <sub>1</sub>	JAMF <sub>1</sub>	JS	JMF <sub>1</sub>	JMF <sub>1</sub>	JMF <sub>1</sub>	JMF <sub>1</sub>
Length of pygidium	44	48	21	21	27	26	16	16
Anterior width of pygidium	13	21	15	15	11	16	28	28
Length of pygidial axis	22	36	24	24	19	13	13	13
Frontal width of axis	12	19	13	13	8	6	6	6
	6.5	10.5	7	7	5	5	5	5

Remarks :

The material constitutes the topotype. Damesella paronai ( Airaghi ) differs from this form in having a relatively short glabella, palpebral lobes situated at the glabellar mid length. As regards to pygidium D. paronai does match in having six pairs of pygidial marginal spines but only the first pair of the spine ( counting from anterior to posterior ) is long, whereas all other pairs of spines are of nearly equal length.

The Kashmir form also shows some affinity to D. blackwelderi Walcott but differs from it in the presence of well defined lateral glabellar furrows. Moreover, the rounded pit near the margin of the posterior pair of glabellar furrows as seen in D. blackwelderi is also absent. The specimens also have other minor differences such as location of palpebral lobes slightly anterior to the glabellar mid length, transverse nature of the anterior, border and the converging course of the anterior part of the facial suture.

Of the four species of Damesella described by Resser and Endo ( 1937 ) viz., D. conica, D. nitida, D. quadrata and D. walcotti; Opik ( 1967 ) has suggested the exclusion of first two i.e., D. conica and D. nitida from genus Damesella, on the basis of these two possessing a narrow preglabellar area.

The remaining two species that is D. quadrata and D. walcotti do not match with D. shergoldi. D. quadrata differs in having an abruptly expanded frontal glabellar lobe with an almost parallel sided glabella and with a pygidium having seven pairs of pygidial marginal spines. Though D. walcotti has six pairs of pygidial marginal spines but the relative length and position of these spines do not match with D. shergoldi.

D. torosa Opik with very faint vestigial ocular ridges, characterised by the combination of a conical glabella with an expanded glabellar frontal lobe, narrow and shallow pygidial pleural furrows, broad and flat pleural ribs, a long first pygidial marginal spine and rather a very long and thick fifth pygidial marginal spine do not match with D. shergoldi.

Horizon and locality :

The specimens have been collected from Damesella Zone of Trahagam Formation, at Jagarpura waterpoint in the Kupwara district of Kashmir and lies in the Damesella Zone. It is restricted only to early Late Cambrian and in this respect it correspond to uppermost range of D. torosa in Australia.

Genus : BLACKWELDERIODES Húpe, 1955

Blackwelderiodes monkei ( Walcott )

( Plate E, 17 & 19 ).

Stephanocare ? monkei Walcott, 1911, pp. 69-118

pl. 14 - 17

Blackwelderiodes monkei ( Walcott) Húpe 1955,

pp. 91-325 ; Figs. 93-247.

Material :

Two pygidia in a poor state of preservation in blocks of light green shale.

Description :

Pygidium subtriangular, width slightly greater than the length, axis of pygidium tapering posteriorly, bearing four axial rings and terminal, pleural field wider than the axis, five pleural furrows running into base of spines, border furrow shallow, border poorly defined bearing seven pairs of marginal spines, 1st pair counting from anterior to posterior much longer than others, fifth pair stands next in length, all other pairs smaller.

Dimensions : (in mm )

	<u>Specimen numbers</u>	
	<u>TRS-11</u>	<u>TRS-12</u>
Length of pygidium	4.2	5.0
Anterior width of pygidium	4.8	6.5
Length of axis	2.5	4.5
Frontal width of the axis	0.8	2.0

Remarks :

The specimens corresponds to Blackwelderiodes monkei in most of the pygidial morphological characters especially in the pattern of marginal spines, anterior width greater than length and also its subtriangular outline.

Horizon and locality :

The specimens have been collected from the Trahagam Formation, near Trahagam village.

Subfamily : DREPANURINAE Húpe, 1953  
 Genus : PARABLACKWELDERIA Kobayashi, 1942

Parablackwelderia sp.

( Plate E ; Fig. 9, 10 )

Material :

Two pygidia in a poor state of preservation in blocks of greenish shale.

Description :

Pygidium semicircular, anterior width slightly more than double its maximum length, pygidial axis tapering posteriorly, bearing three axial rings and terminal, pleural field moderately convex, equal to axis in width with 5 pleurae, 5 pairs of pleural furrows, border furrow nearly obsolete, narrow flat border with seven pairs, of pygidial spines, 1st pair of pygidial spines ( counting from anterior to posterior) much longer than others and all other pairs of spines smaller.

Dimensions : ( in mm )

	<u>Specimen numbers</u>	
	<u>TRF -37</u>	<u>TRF-38</u>
Length of pygidium	6.5	7.4
Anterior width of pygidium	11.8	12.4
Length of the axis	3	3.8
Frontal width of the axis	3.5	4.5

Remarks :

The specimen corresponds to Parablackwelderia in most of its pygidial morphological characters especially in having a semicircular shape, width greater than length, three axial rings and pattern of the marginal spines. However, the form does

not match with the only known species, P. spectabilis because pygidium of P. spectabilis is characterized by a very long 1st and 5th pair of pygidial spine. The specimen differs from Blackwelderiodes monkei from the same stratigraphic horizon of Kashmir, as the latter has subtriangular outline, in the length width ratio and pattern of the pygidial spines. It is not possible, however, to assign these specimens to a new species, because of poor state of preservation and also due to lack of any associated cranidia.

Horizon and locality :

The specimens have been collected from Trahagam section near village Trahagam.

Suborder	:	ASAPHINA Salter, 1864
Super family	:	ASAPHACEA Burmeister, 1840
Family	:	TSINANIIDAE Kobayashi, 1933
Genus	:	<u>DICTYITES</u> Kobayashi, 1936

Dictyites sp.

( Plate E, 12, 13, 16 )

Material :

Four cranidia poorly preserved in fine sandy shale.

Description :

Cranidium subquadrate in outline, length greater than width, anteriorly rounded, gently convex. Glabella nearly Parallel sided, rounded in front, length being more than double its posterior width and occupies about two third of the total cranidial length, lacking lateral glabellar furrows, axial furrow distinct, preglabellar furrow shallow, the furrow which separates the preglabellar field and anterior border is not clearly visible, however, the frontal area is wide, flat and downsloping from the preglabellar furrow. Eye ridges distinct eye of medium size and situated opposite the glabellar mid length; Fixigenae downsloping with palpebral areas about 0.5 the glabellar width. Facial suture divergent in front of the palpebral lobes but turn sharply and extend in a broad curve inward after reaching border. Posterior course divergent behind eye lobes. Frontal limb straight.

Dimensions : ( in mm )

	<u>Specimen numbers</u>		
	<u>JARS-1</u>	<u>JARS-3</u>	<u>JAS-61</u>
Total cranidial length	11.0	9.8	12.5
Posterior cranidial width	9.0	8.5	9.5
Total glabellar length	8.2	7.4	9.0
Glabellar width at base	4.5	3.2	4.8
Width of the anterior border	0.5	0.3	0.6
Width of preglabellar area	.2.5	2.2	2.5
Width of cranidium at eye lobes	8.5	7.5	8.0

Remarks :

The specimen correspond to Dictyites in all its cranidial morphological details, especially in the general outline of the cranidium, in the glabellar characteristics, lacking in lateral glabellar furrow, obsolete anterior border furrow and position of eyes. However, they do not match with any of the known species of this genus. D. dictys the genotype differs in having a shallow anterior border, obsolete eye ridges and in the shape of its glabella. D. trigonalis Kobayashi ( 1936 ) show remarkable difference in the presence of a cranidium with subtriangular outline, shallow concavity behind the anterior margin, comparatively large posteriorly situated eyes and lacking in eye ridges. D. depressa Kobayashi ( 1936 ) do match in possessing distinct eye ridges but it also has a distinct anterior border furrow which differentiate between preglabellar area and anterior border and eyes situated posterior to glabellar mid length and in these respects differ from Kashmir form.

As the material is very scanty, so a new species cannot be established.

Horizon and locality :

The specimens have been collected from Damesella Zone of Trahagam Formation, in the Magam section.

Genus : TSINANIA Walcott, 1914

Tsinania sp.

( Plate E, 20 - 23 )

Material :

Six cranidia in tolerable state of preservation, in blocks of dark grey shale.

Description :

Cranidium elongated, subquadrate in outline, moderately convex, tapering anteriorly, slightly more in length than the posterior cranial width. Anterior border narrow, moderately flat, of uniform width, gently arched at the front. Preglabellar area narrow, of uniform width, slightly more in width than the anterior border. Glabella rounded anteriorly, parallel sided, gently convex, glabella occupies about seventy per cent of the total cranial length. Length of the glabella about one and half time more than its width at the base. Three pairs of faint lateral glabellar furrows, of which the posterior one is relatively more distinct, axial furrow narrow, shallow, occipital furrow shallow, straight, occipital ring wider at the centre and moderately arched backward. Eye ridges faint, gently oblique, starting at the first lateral glabellar furrow, eye of small size and situated between second and third lateral glabellar furrow nearly at the glabellar mid length.

Fixed cheek narrow, elongated, its width slightly less than the total cranidial length, gently convex, upsloping but not raised upto the level of glabella.

Dimensions ( in mm. )

	<u>Specimen Numbers</u>		
	<u>SSPF<sub>7</sub>-25</u>	<u>SSPF<sub>7</sub>-39</u>	<u>SKF<sub>7</sub>-27</u>
Total cranidial length	5.1	5.0	6.5
Posterior cranidial width	4.8	4.9	6.0
Total glabellar length	3.7	3.5	4.8
Width of the glabella at base	2.0	1.9	2.5
Sagittal width of preglabellar area	0.7	0.6	1.0
Sagittal width of anterior border	0.5	0.5	0.5
Width of the cranidium at eye lobes	4.2	4.5	5.5

Remarks :

In having a subquadrate, moderately convex, anteriorly tapering cranidium, glabella outlined with narrow and shallow dorsal furrows on both sides, shallow lateral glabellar furrows, small eyes situated at the glabellar middle length and an

occipital ring which is wide at the centre and moderately arched backwards the specimens can easily be referred to Tsinania.

However, this form does not match with any of the known species of this genus. T. canens Walcott ( 1914 ), the genotype, differs in having very shallow to nearly obsolete border furrow, glabella almost straight at the front and posteriorly it slightly diverges towards the occipital furrow, fixed cheek in front of the palpebral lobe is rather narrow, postero-lateral limb short and narrow.

T. ceres Walcott ( 1914 ), T. peipingense and T. tingtaohengi Sun ( 1935 ) are based on pygidia only, therefore, no comparison can be made with the Spiti form in the absence of any associated pygidium.

On the basis of elongated nature of cranidium the Spiti form is more close to Tsinania acuta Sun ( 1935 ) but T. acuta has a strongly convex cranidium, frontal border is acutely rounded with an angle of  $90^{\circ}$ , the palpebral lobe elongate, situated slightly below the glabellar mid length and a very characteristic outline of the facial suture and in these respects this form does not match with Spiti form.

The specimens also show some resemblance to Manchuriella Kobayashi ( 1935 ) especially in having small preglabellar field, shallow lateral furrow and short palpebral lobes but Manchuriella has a broad glabella which is straight at the front, border furrow very prominent, distinct eye ridges and in these characters it differs from Spiti form.

As the material comprises of only six poorly preserved cranidia a new specific name cannot be given to it.

Horizon and locality :

The form has been collected from Olenus Zone in Parahio section, Parahio Valley, Spiti.

CHAPTER - VI  
FAUNAL PROVINCIALISM AND CORRELATION

Faunal Provincialism in Cambrian :

From very early times no worker of Cambrian faunas has failed to note that in Early Cambrian and to certain extent in the Middle and Late Cambrian, the faunas of different parts of the world have not been

the same and are geographically localized in certain specific regions. Infact it was the pioneer of Cambrian stratigraph y, Charles D.Walcott ( 1891 ) who recognized palaeogeographical provinces in the Cambrian of North America as distinct structural and geographic entities. They remain a necessary basis in the study of Cambrian faunas, though the number of provinces has been amplified by subsequent workers.

The concept of faunal provinces is very complicated as the term " province" itself has been used in different senses by various workers. However, as is commonly accepted now, there are three terms which cover all the aspects of faunal provincialism and these are :-

- a) Palaeogeographical province - means a geographical region with a distinct fauna in the past.
- b) Realm - some kind of a superregion which can be further subdivided into a number of smaller provinces on the basis of geographic, tectonic and environmental factors.
- c) Magnafacies - a province based on the ecological conditions represented by the rock facies ( equivalent

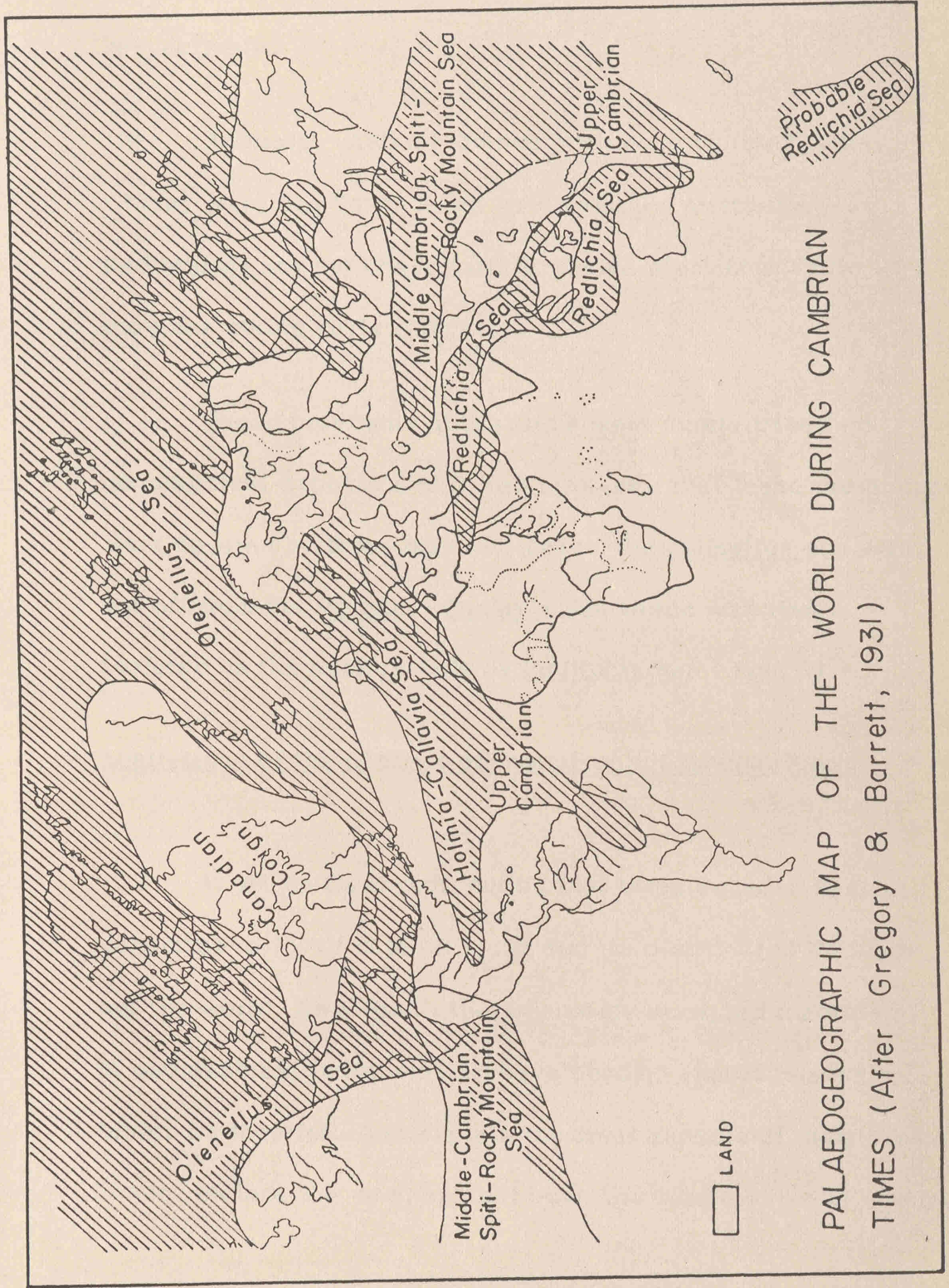
to the biomes of present day zoologist ).

Earlier ideas of Geographic Provincialism :

Cambrian faunal provinces have been the subject of much discussion. One of the earliest work was by Grabau (1910) who identified three different faunal provinces during Cambrian. Following Grabau with slight modifications Gregory and Barrett ( 1931 ) have identified three different provinces exclusively based on trilobites and named them as :

- i) Pacific Province - which covered western parts of North and South America and other such areas which border the Pacific Ocean and is characterized by Olenellus in Early Cambrian and Bathyriscus in Middle Cambrian . They even suggested that Pacific Province also covered Spiti in Himalaya during Middle Cambrian times ( Fig. 11 ).
- ii) Atlantic or Acado - Baltic Province - which centred about Europe, north eastern parts of United States, adjoining parts of Canada including Newfoundland and South America, where Holmia - Callavia, Paradoxides and

Fig. 11



PALAEOGEOGRAPHIC MAP OF THE WORLD DURING CAMBRIAN TIMES (After Gregory & Barrett, 1931)

olenids represent Early, Middle and Late Cambrian respectively.

iii) Australo - Asian Province - which comprises India, China, Iran, Far East, South east Asia and Australia. Redlichiids are the characteristic faunal elements of this province during Early Cambrian.

These provinces at that time were purely based on geographical aspects and it was presumed that these provinces were covered by three different seas. The Olenellus sea was cut off from the Holmia - Callavia sea which was itself isolated on the eastern side by Redlichia sea ( Fig- 11 ).

Limitations of the concept of geographic Provincialism :

Work on Cambrian during last three decades has generated a lot of data on fauna and its distribution throughout the world. As a result the commonly accepted theories of geographical provincialism have become almost unacceptable, as they failed to explain the finer aspects of distribution. These include the geographical boundary limits of these provinces

which were somewhat loosely defined . For example the occurrence of Redlichia a characteristic Early Cambrian faunal element of Australo-Asian Province in parts of Spain in southern Europe and Morocco in northern Africa, the areas which should theoretically belong to Atlantic Province, can not be explained. Similarly Fallotaspis an important Early Cambrian genus of Atlantic Province has been reported from several localities in Pacific Province. In Siberia the situation is more complex because here not only Redlichia and Holmia - Call<sup>a</sup>ylia but even some possible olenellids of the Pacific Province are found in association. Likewise Antarctica which is situated very close to Argentina does not share a single trilobite genus with the Cambrian of that region. On the other hand the Cambrian fauna of Antarctica includes elements of redlichiidae in Early Cambrian, Xystridura, Amphoton and certain ptychoparids in Middle and Late Cambrian, which are closely related to Cambrian fauna of Australia, China, Siberia and Kazakhstan.

During the Middle Cambrian the influence of geographical provincialism is very limited, as several important elements of Paradoxides fauna which were once thought to be characteristic of Atlantic Province have been reported from several areas of other

provinces. Even some characteristic genera of this province show a trend towards becoming cosmopolitan and same is the case with Bathyriscus fauna of Pacific Province.

The Late Cambrian exhibits an entirely different picture, where the geographical provincialism does not exist at all. For example the members of olenidae which were thought to be characteristic of Atlantic Province and dikelocephalidae of Pacific Province have been found in several areas outside their respective geographical limits.

This mixing of fauna of different provinces and the occurrence of faunal elements supposedly characteristic of a typical faunal province, outside the limits of that particular province cannot be explained by geographic provincialism. Secondly, the global distribution of agnostids, an important group of trilobites, which form the basis of present day bio-stratigraphic zonation and correlation of Middle and Late Cambrian, is very perplexing. The earlier concept that provinces represent different seas which were isolated by geographic barriers by way of landmass is

unable to explain the world wide distribution of this group, which has majority of cosmopolitan elements at the generic level and quite a few at the specific level too.

Modern opinions on Cambrian provincialism :

To clear this controversy regarding erratic geographic distribution several alternative explanations were offered by various workers. Some of the important among them are summarized below :-

Opik ( 1957 ) while admitting the commingling of Cambrian fauna, suggested that isolation may be regarded as the rule, and explained that intermingling of faunas may occur in two ways viz., (i) as a commingling of contemporaneous faunas over a shorter or longer range of time and (ii) as a sequence of faunas of various provinces replacing one another in time within one and the same geographical region, or even within a local section. He further stated that the two cases are not the only alternatives, because diverse combinations of both are possible and the discovery of intermingling of faunas in a region is, of course, only possible when two other faunas are already known elsewhere which have little in common and are believed to be pure. According to him, the names of

the faunal provinces are more or less priority names and refer to the accident of first discovery, which itself is no guarantee that the fauna in question is pure and not a blend. For example, the Middle Cambrian agnostids of northwestern Queensland are Acado - Baltic, but the diversity of Australian agnostid fauna may suggest that the Baltic region itself got only a selection of the Acado-Baltic agnostids.

Lochman - Balk and Wilson ( 1958 ), in their epoch - making synthesis of North American Cambrian biogeography, while rejecting the theory of geographical provincialism, recognized three apparently concentric biofacies realms, characterised by both tectonic and environmental criteria. A cratonic realm characteristic of the shallow shelves, an extracratonic intermediate realm characteristic of the miogeosynclines and an extracratonic - euxinic realm characteristic of the eugeosynclines. According to them the faunas of the first two realms have been traditionally representative of the Pacific Province and the Atlantic Province is represented by the faunas of extracratonic - euxinic realm.

On the basis of trilobites Cowie ( 1960, 1971 )  
divided Early Cambrian into two global realms .

1. Olenellid - which is subdivided into (a) Acado -  
Baltic Province, (b) Pacific Province .
2. Redlichiid .

The Redlichiid realm is characterised by the  
presence of the genera of the superfamily redlichiacea  
and is represented in Australia, Indo - China, China,  
Korea, Manchuria, Central eastern and arctic Siberia,  
Iran, Pakistan, India, Jordan, Antarctic, Spain and  
Morocco .

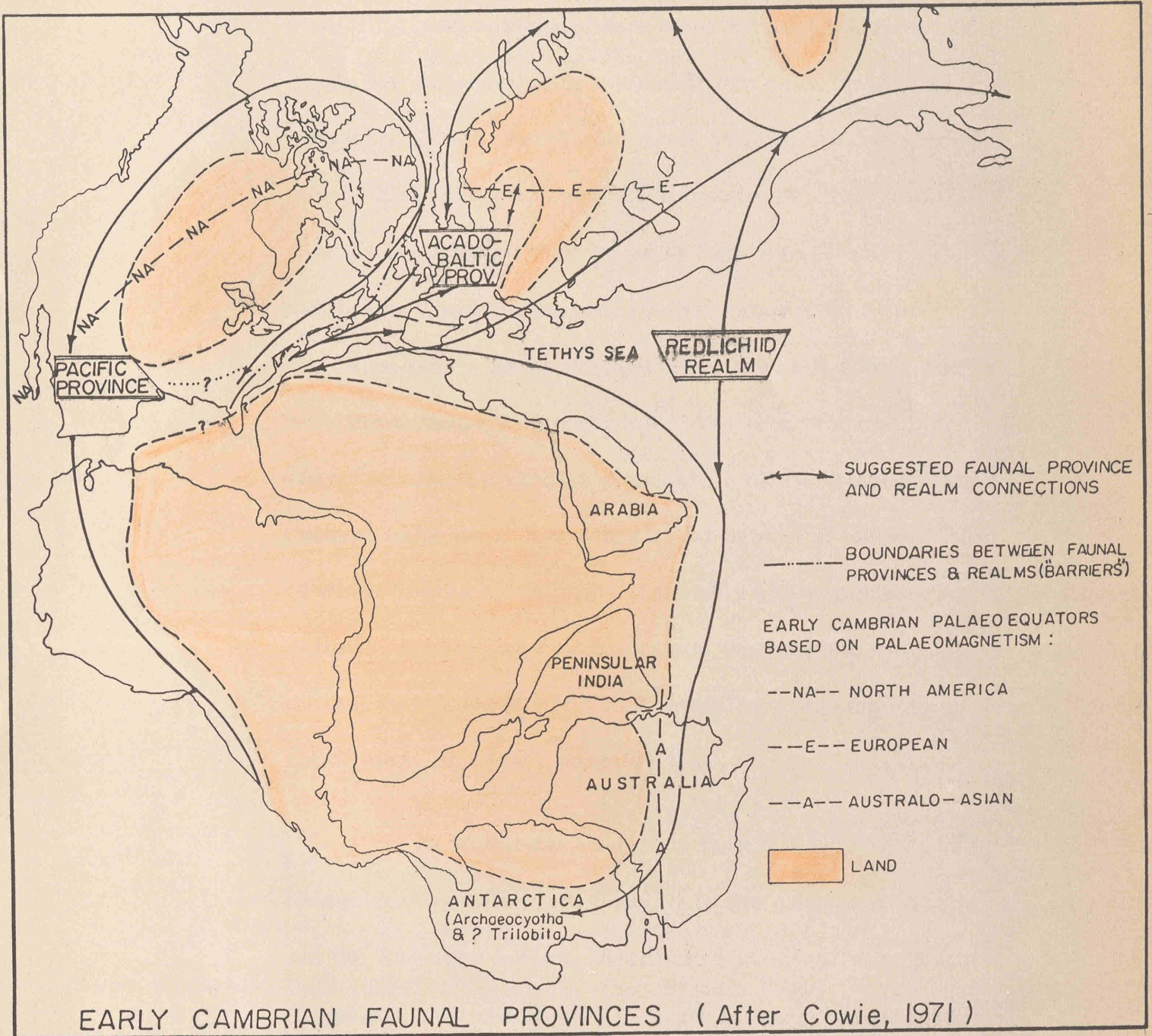
The Acado - Baltic Province is characterised by the  
olenellids, Callavia, Kjerulfia and Holmia, with the ellipso-  
cephalids Strenuaeva and Strenuella. This fauna occurs in  
Wales, England, Norway, Sweden, Denmark, Germany,  
Poland, north-west Russia, France, Spain, Portugal,  
Morocco, eastern Newfoundland, Nova Scotia and eastern  
North America .

The Pacific Province is characterised by the

olenellids Olenellus, Paedeumias, Nevadia and Nevadella with the dorypygids Bonnia and Bonniella. The fauna occurs in Western North America, British Columbia, Greenland, north-west Scotland, western Newfoundland, Mexico and possibly in Argentina.

The Early Cambrian faunal provinces as suggested by Cowie ( 1971 ) and realm connections are shown in Fig.12. The heavy lines and arrow heads are purely diagrammatic and do not necessarily imply centres of populations or stocks and migration routes but merely serve to connect and relate parts of the realms or provinces.

However, none of the realms or provinces is completely exclusive of the others. For example olenellids and genera of the redlichiacea occur together in Morocco, near the western end of Mediterranean and in Siberia. Similarly Holmia a traditionally Acado - Baltic genus occurs in north -west and east Greenland and Siberia. Fallotaspis and Fallotaspidella of the family olenellidae occurs in Morocco, England, California and eastern Siberia. Strenuaeva occurs in north-west Greenland and Bathynotus occurs in arctic Siberia.



Cowie ( *op. cit.* ) presumed that areas with evaporitic sedimentation were situated near the Early Cambrian palaeoequator, derived from palaeomagnetic evidence. Trilobites, brachiopods and other phyla were widely distributed in Early Cambrian times. From this it might be inferred that the seas were universally habitable. Thus the evidence might suggest that Early Cambrian times had a uniform climate which contrasted with the widespread glaciation of the late Precambrian. Therefore, the provincial distribution of the faunas could, perhaps have been controlled by (i) depth (ii) segregation of water bodies by differing chemistry and especially salinity, organic and food content, temperature and current circulations (iii) sedimentation affecting living conditions, and (iv) possibly land.

In Southeast Asia, two facies realms have been recognised by Kobayashi ( 1967 ) in the Cambrian. These are the Hwangho facies, distributed principally in North China and also recognised in North Vietnam border region, and the Yangtze or Machari facies of east - central and western China and South Korea.

During the Early Cambrian the region of the Hwangho facies was the site of shale deposition and is characterised by the presence of species of Redlichia. The region of the Yangtze facies included significant areas of carbonate sedimentation and the associated trilobites included a few eodiscidae in addition to Redlichia and some protolenidae.

During the Middle Cambrian, the Hwangho facies reflects shallow - water carbonate sedimentation grading northward in North China and Korea into increasingly terrigenous sediments. The trilobite faunas are largely endemic and include such typical genera as Amphoton, Solenoparia and Anomocarella. The contrasting Yangtze and Machari facies are characterised by shaly and silty sequences with associated thin bedded pyritic limestone suggestive of deeper water conditions. In north-western China, volcanic rocks are associated with this facies. The trilobite faunas of this facies are characterised by cosmopolitan agnostid genera.

Towards the end of Middle Cambrian and in the early Late Cambrian, the Yangtze facies spread into parts of

the northern region where it is represented by a variety of genera of the *damesellidae*. During the remainder of the Late Cambrian, the regions of the Hwangho facies were again dominated by endemic trilobites. The area of the Yangtze facies continued to have a cosmopolitan agnostid fauna.

Palmer ( 1969 ) offered an alternative interpretation of concentric faunal relationship during Cambrian times, which instead of tectonic and environmental criteria of Lochman - Balk and Wilson (op. cit. ), exhibited that lithofacies acts as a major factor in the faunal patterns during Cambrian times. He recognised three provinces on the basis of lithofacies. A broad belt of carbonate sediments, largely reflecting extremely shallow water conditions across a broad carbonate platform, an inner region of light coloured terrigenous sediments ( inner detrital belt ) which reflects shallow water conditions and an outer region of dark grey or black silty and shaly sediments ( outer detrital belt ), often associated with dark coloured, thin bedded limestone, that reflect deeper water conditions. The carbonate belt separates the inner

detrital and peripheral belts. Most of the deposits of the carbonate platform ( exclusive of its seaward edge ) and of the inner detrital belt contain the faunas of the cratonic realm, while the deeper water sediments of the outer detrital or peripheral belt contain faunas characteristic of the extracratonic - intermediate realm of Lochman - Balk and Wilson.

The fauna become increasingly varied and cosmopolitan towards the most peripheral regions. The fauna of inner detrital belt consists largely of endemic species and genera of non - agnostid trilobites while the peripheral regions contain significant number of eodiscidae, oryctocephalidae and pagetiidae in parts of the Early Cambrian to middle Middle Cambrian, and a variety of cosmopolitan agnostids from late Middle through Late Cambrian.

Palmer ( 1972 ), however, came to the conclusion that the striking similarities between faunas of all ages in Antarctica with those of Siberia and other areas bordering the western Pacific, the comparable striking resemblance of the Cambrian faunas of Argentina to those of North America,

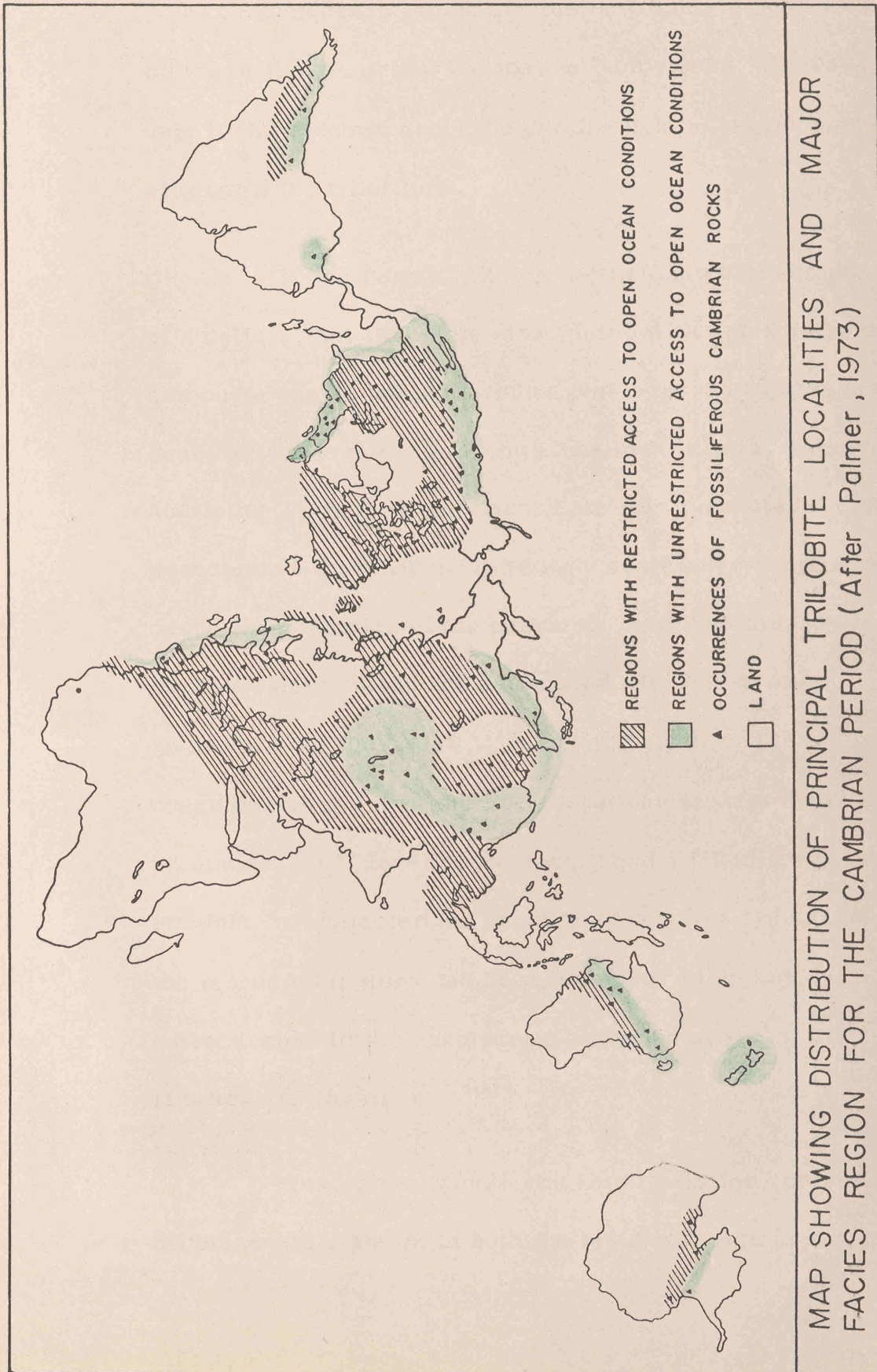
and total dissimilarity of the Argentine faunas to those of Antarctica must be taken into consideration in any reconstruction of the Cambrian world. The similarities may be explained most easily by the idea of common palaeolatitudes for regions that share similar faunas. The contrast between the Cambrian fauna of South America and Antarctica, which should have shared relatively nearby areas of a common coastline according to reconstruction of Gondwanaland, may possibly be explained by latitudinal differences, but it may also indicate that these areas were not part of Gondwanaland until post-Cambrian times.

Palmer ( 1973, 1979 ) gave an entirely new concept for Cambrian faunal provincialism. He remarked that neither the geotectonic criteria of geosyncline versus craton ( Lochman - Balk and Wilson, 1958 ) nor the lithofacies pattern of carbonate banks and inner and outer detrital belts ( Palmer, 1969 ) are applicable on a world wide basis to explain the general trilobite distribution. The major faunal contrast on the largest scale are between those areas that had unrestricted access to the open ocean

and those areas where such access was restricted either by a carbonate barrier, or by undefined modifications of environmental parameters such as temperature and salinity that were related to broad expanses of shallow sea over either carbonate or terrigenous substrates. Areas of the first type are the agnostid rich areas that share many common faunal characteristics on a global scale. Areas of the second type are those areas where endemic polymerid genera dominate. If trilobite distributions are viewed in this context of contrasting marine environment, restricted versus unrestricted access to open ocean conditions, then a reasonable explanation for both the intracontinental diversity and intercontinental similarity of the trilobite faunas can be found.

Fig. 13 shows the general distribution of persistent areas of open ocean and restricted conditions during Cambrian times as suggested by Palmer. (*op. cit.*). The margins between these areas fluctuated throughout the Cambrian and in addition are not sharply defined. Thus the boundaries on the map indicate only an approximate average position on a shifting spectrum of conditions within this broad framework.

Fig. 13



Both the open ocean region and the restricted regions supported biotas of limited extent that define "provinces". Because very little is known about the precise habitat requirements for almost all the trilobites.

In the Early Cambrian the rich and varied faunas of Asiatic Soviet Union are associated with broad areas of carbonate banks, whose margins were exposed to open ocean conditions. Most western North American, Arctic, Asian and Australian Early Cambrian faunas are from restricted regions associated with terrigenous sequences of inner detrital belt or the inner margins of the carbonate belt. The faunas of south-western Europe are associated with terrigenous sequences but they seem to have had better access to open ocean conditions than the North American faunas. Two provinces, an "Olenellid Province" and a "Redlichiid Province", characterised by trilobite families typical for the restricted regions can be recognised. In regions with better access to the open ocean, representatives of both families are known.

During the Middle and Late Cambrian, provincial differences are shown in both the restricted regions and open

ocean regions. In the restricted regions four provincial areas typified by many endemic genera and species can be recognised (i) the inner detrital belt and adjacent margins of the carbonate belt of North America (2) the sandy facies of Central Europe (3) the carbonate banks of Siberian platform, and (4) the Hwangho facies of China. The Late Cambrian sandy facies of Australia seems to have a close relationship to Hwangho facies.

In the regions with unrestricted access to the open ocean, the number of provincial areas is less and they are poorly defined. Three provinces focussed on western Europe, North America and Australo - Asia can be recognised. The western European Province is characterised by the olenidae, conocoryphidae and paradoxididae. Significant elements of the fauna of this province are found in the open ocean regions of Asiatic Soviet Union, in extreme eastern North America and Asia. However, the North American Province is characterised by oryctocephalidae, certain corynexochida (Bathyriscus, Ogygopsis, Zacanthoides), marjumiidae, pterocephaliidae, richardsonellidae and catillicephalidae. Some of the typical elements of this province are found in the open

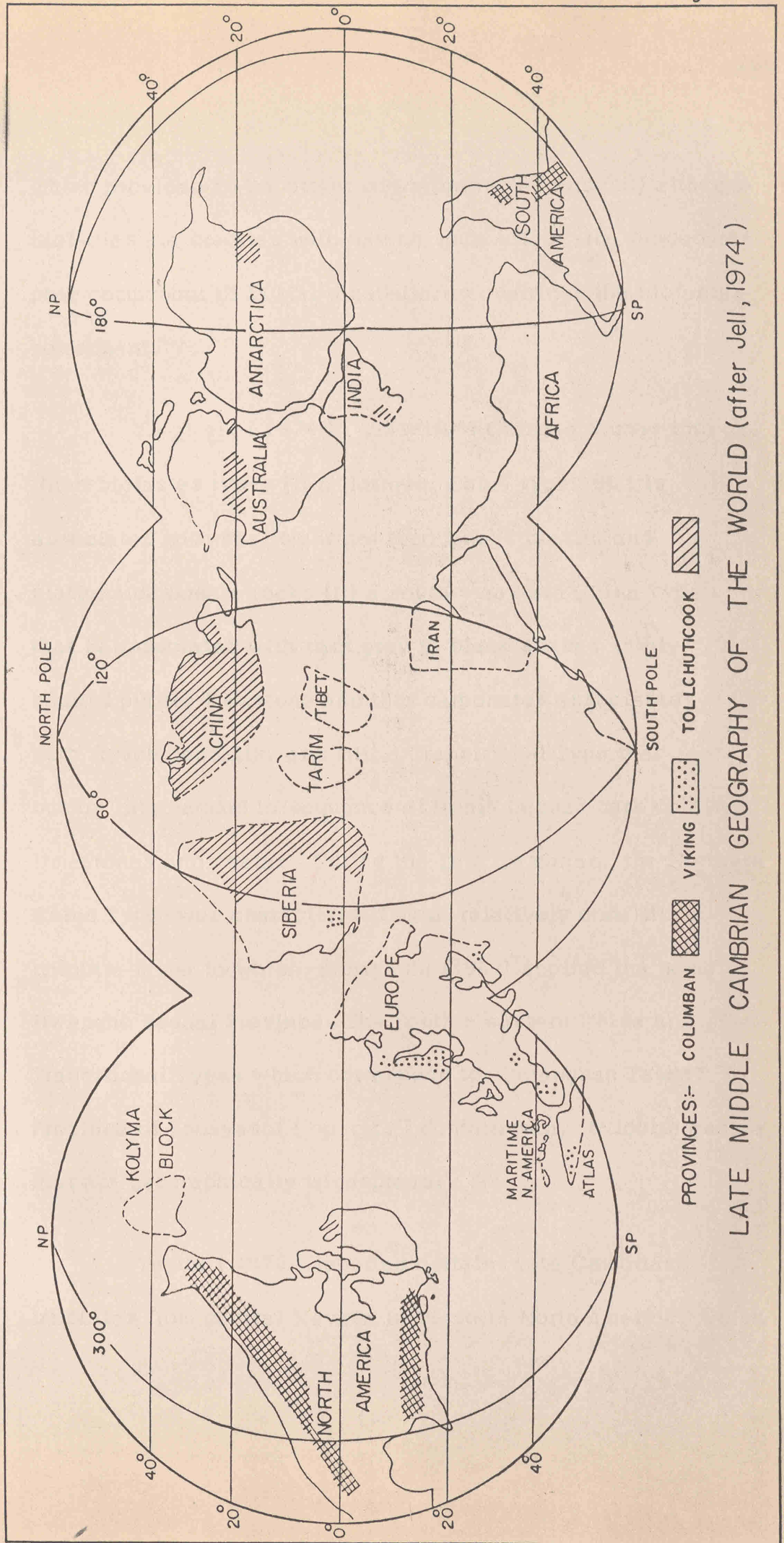
ocean regions of Asiatic Soviet Union, South America, Australia and Asia. The Australo-Asian Province is characterised by damesellidae, certain corynexochidae (Amphoton), anomocarellidae, ceratopygidae and xystridurinae. Some elements of these faunas are found in the open ocean regions of Asiatic Soviet Union, north western North America and in Antarctica.

Jell ( 1974 ) has attempted to study the provinciality by cluster, principal component and discriminative analysis of the available faunal data for Middle Cambrian. According to him the usefulness of statistical procedure in palaeobiogeographical studies is that areas are not grouped on the basis of a few common genera but on comparisons of their total faunas with all other parts of world. Three provinces were recognised by Jell ( op.cit. ) which were not given geographical names. Instead the provinces were named in honour of famous seafarers of that province. The three provinces are (i) Columban - which include North and South America (2)Viking - comprising Europe, northwestern Africa and maritime North America, and (3) Tollchuticook - consisting of Asia, Australia and Antarctica.

According to him the occurrence of Early Cambrian redlichiids in Spain and Morocco is not surprising, since several

other genera must also have migrated between Siberia and the Mediterranean. The Tollchuticook or redlichiid realm occurrences of the genus Redlichia exhibit considerable diversity of species of number of specimens, whereas the few fragments in Spain and Morocco indicate a possible chance of extra-provincial migration. Moreover, the provincial affinities of the total Spanish and Moroccan fauna are clearly Viking or Atlantic, so Redlichia should not be used to indicate a faunal provinces.

Fig. 14 shows the Middle Cambrian palaeogeography of the world as suggested by Jell (op. cit.). Areas covered by sediments of this age are indicated by symbols appropriate to the particular faunal province. As can be seen from this figure, an obvious feature of this proposed reconstruction is that majority of sediments yielding Middle Cambrian faunas are situated within  $30^{\circ}$  of the Palaeoequator. A few faunas occur between  $30^{\circ}$  and  $40^{\circ}$  but none occur at higher latitudes, therefore, the influence of latitudinal variations is minimum. He concluded that (i) Gondwanaland was probably not a single continent in the Middle Cambrian but was crossed by a wide sea,



LATE MIDDLE CAMBRIAN GEOGRAPHY OF THE WORLD (after Jell, 1974)

which provided an important migration route, and (ii) although biofacies are credited with having some effect, the biogeographic component of faunal dissimilarity overrides the biofacies component.

Lu et al. ( 1974 ) classified Chinese faunas into three biofacies types (i) a Northern China type, that is associated with shallow water terrigenous clastic and platform carbonate rocks (ii) a south - eastern China Type that is associated with dark grey to black shale , thinly bedded pyritic limestone and thin carbonates associated with flysch deposits, and (iii) a Transitional Type that occurs interbedded in sequence of thinly bedded dark coloured limestones and shales. During the Late Cambrian, the Northern China Type was characterised by a relatively endemic trilobite fauna to which Kobayashi (1967) applied the name Hwangho Faunal Province. The South - eastern China and Transitional Types which correspond to Chiangnan Faunal Province of Kobayashi ( op.cit. ) contain many trilobite genera that are geographically widespread.

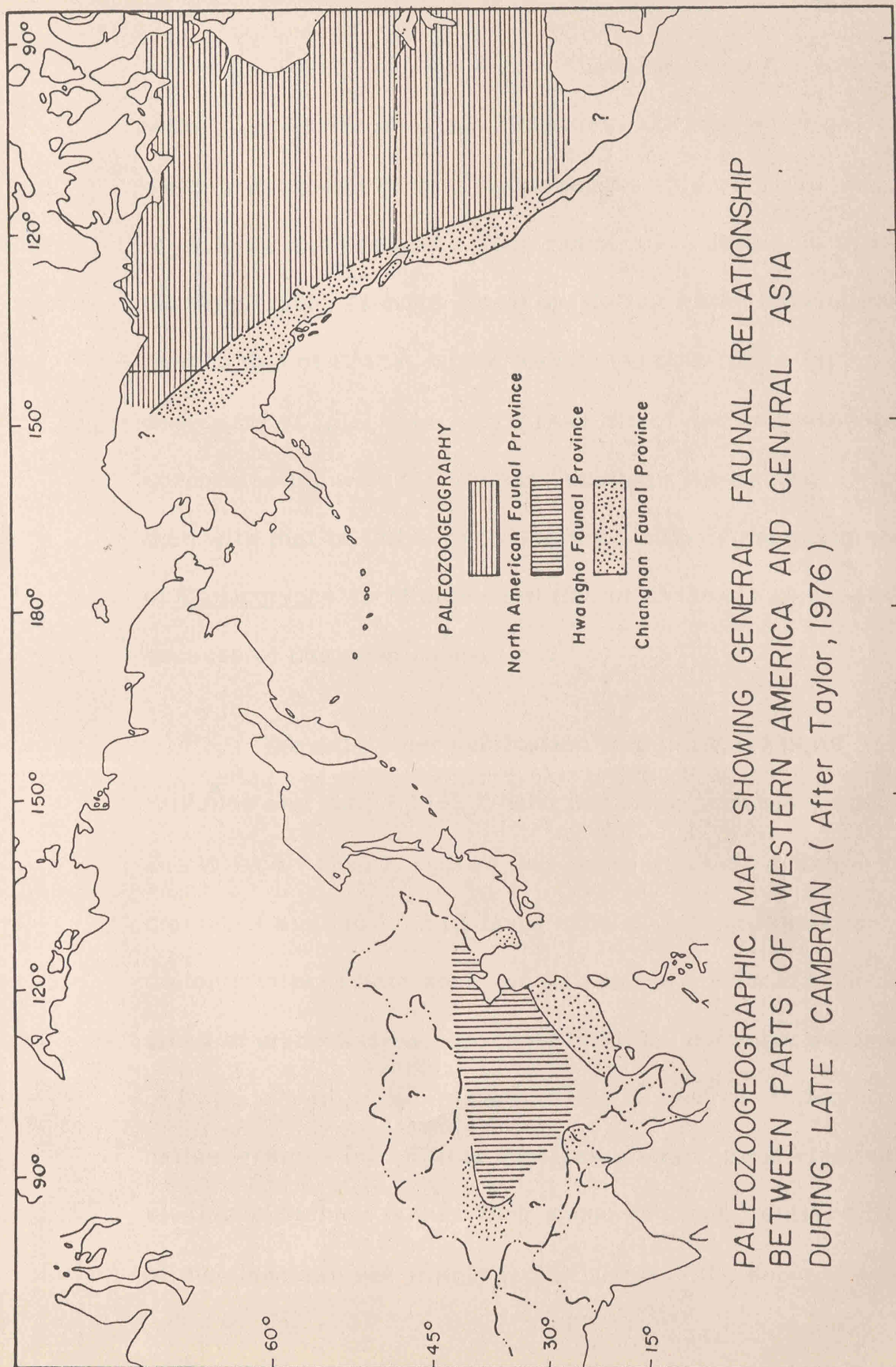
Taylor ( 1976 ) reported certain Late Cambrian trilobites from central Nevada in Western North America, which

are characteristic of Chiangnan Faunal Province and explained these occurrences on the basis of environments. Fig.15 show general faunal relationships between parts of western North America and central Asia during the Late Cambrian as suggested by Taylor. These relationships show that, in general, Late Cambrian faunal provinces are a reflection both of different faunas occupying different major marine habitats in adjacent areas, and of different faunas occupying similar habitats in widely separated areas. The Chiangnan Faunal Province contained a fauna that lived in Late Cambrian deeper water basinal habitats, whereas the Hwangho and North American Faunal Provinces represent geographically separated shallower water shelf habitats in China and North America respectively.

Provincialism in relation to Himalayan Cambrian :

Prior to the present studies not much work was done on provincialism of Himalayan Cambrian, which is a part of Australo - Asian Super - region. One of the earliest publications which refers to Cambrian palaeogeography in respect to Himalaya is that of Pascoe ( 1959 ), who recognized two distinct arms of Tethys sea in this province. One of these extended westwards along the Himalayan " geosyncline", that

Fig.15



is Spiti, Kashmir and Salt Range, across southwest Persia to Mesopotamia, and has all the characters of a shallow water epi-continental sea. The other arm trended north westwards across Yunan, Shantung and Shansi, as far as Manchuria and perhaps a little further to Siberia. He remarked that Spiti fauna is much closer to that of Rocky Mountains than to that of China, which lead to the conclusion that eastwards of Spiti there was a more direct and uninterrupted communication with the Western American subprovince than with that of China to the north. Similarly the occurrence of Conocoryphe in Middle Cambrian of Kashmir was suggested because of European connection.

The only other publication in this regard is by Wakh<sup>a</sup>loo and Shah ( 1965 ), who following Lochman - Balk and Wilson ( 1958 ), opined that Kashmir fauna is extra-cratonic ( euxinic ), Spiti fauna more or less of the extra-cratonic intermediate zone and Salt Range represents the fauna of cratonic type. Similarly towards the north the fauna of China, South Korea and Manchuria is also of cratonic nature whereas Indo-China contains extracratonic elements similar to Kashmir fauna. They suggested that central part of the Cambrian sea in this region showing the deepest zones

are those of Kashmir and Indo-China, whereas margins of this sea are represented by the Salt Range in the South and by China and South Korea in the north, Spiti region being of an intermediate nature. The lithological evidences also supported this distribution. They concluded that in Cambrian times same sea covered the entire Himalayan region and the variation in fauna that is met within Spiti, Salt Range and Kashmir is due entirely to the change of the environmental factors in the three depth zones.

The limited nature of observations regarding the provincial setting of Himalayan Cambrian is understandable because only spot faunas from Kashmir, Spiti and Salt Range were listed and described at that time. In fact a comprehensive biostratigraphic classification of Kashmir Cambrian came only as late as 1982 ( Shah, 1982 ) and a similar classification on Spiti sequence is still in press. Only during the studies under the Project, of which the present work forms a part, have a comprehensive listing and description of the Cambrian faunas of Himalaya been made. We are, therefore, now in a position to analyse the faunal distribution and draw conclusions on provincialism on the basis of that distribution. It must be, however, emphasized that we are dealing with an extinct group

whose habitat and adaptation has only to be inferred indirectly. This introduces another variable dimensions to the distribution of trilobites. Needless to mention that the data of distribution is essentially empirical and has to be interpreted with applications of all known parameters that influence it.

Though the present work deals only with late Middle and Late Cambrian but for continuity the Early Cambrian and remaining Middle Cambrian faunal provinces are also discussed. The precautions necessary in attempting any analysis of faunal provincialism are :-

- (i) contemporaneity of faunas must be clearly established, and
- (ii) the faunal data should be plotted on reconstructed palaeogeographic maps based on palaeomagnetic data of that period for which provincial studies are taken.

As regards the first precaution, no such clear world-wide correlation existed, which included the latest Middle and Late Cambrian faunal elements of Himalaya. So a global correlation chart for Middle and Late Cambrian which included latest

faunal elements is compiled during the course of present work as a Table ( Fig. 8 ).

Most earlier faunal provincial analyses are based on plotting the faunal data on present day geographic maps which has very little relationship to the geography of the past. Although reconstructions for Mesozoic world was given by magnetic reversals and sea floor spreading, no such data was available for Palaeozoic until Dewey and Bird ( 1970 ) gave Late Palaeozoic reconstructions. However, recently Scotese et.al.( 1979 ) on the basis of palaeomagnetic data gave separate base maps for each period of Palaeozoic. The base maps given by them for the Cambrian are used in the present work for the first time, and all faunal data is plotted on it.

The concept of faunal provincialism involves isolation of faunas by a variety of factors, such as water temperature, salinity, depth, facies etc. Most trilobites being benthonic, might expectedly be susceptible to restriction by the above factors. However, several Cambrian trilobites are thought to have been nektonic and their distribution independent of bottom conditions. The latter include all agnostids.

Early Cambrian itself is divided into Tommotian, Atdabanian and Lenian. The fauna of Tommotian stage comprise archaeocythids, hyolithids, acritarchs etc. but no trilobite has been reported from this stage. The reported first appearance of trilobite is from Atdabanian. Although number of faunal elements of Tommotian stage from the Mussoorie sequence in Lesser Himalaya are reported but these are not taken into consideration as the present studies are purely based on trilobites, because they are the most prolific, variable and widespread Cambrian organisms, and is the only group known well enough to provide a basis for study of faunal provinces.

The late Early Cambrian ( Lenian ) is characterized by redlichiids in the Australo-Asian Superregion. Likewise in Himalaya which is the part of this Superregion, redlichiids have been reported from both Tethys as well as Lesser Himalayan region. In the Tethys Himalaya they have been reported from Kashmir ( Shah et al., 1980 ) and the genus Redlichia is also reported from Spiti ( Reed, 1910 ). In the Lesser Himalaya Redlichia is known to occur in Salt Range and recently redlichiid fauna is known to have been reported from

Himachal Pradesh ( Kumar et al., 1987 ) and Rishikesh ( D.K. Bhatt, personal communication ). The wide distribution of redlichiids in this province led Sdzuy ( 1967 ) to conclude that the Early Cambrian Tethys was a marine connection between Europe ( Spain ), Asia and Australia, serving for faunal migration between the Atlantic Province to the west and Australo - Asian Province to the east.

The Middle and Late Cambrian biostratigraphic correlation as discussed earlier and shown in Figs. 5 & 6, though apparently disjoined leads to some broad conclusions regarding palaeogeography. In the first instance it has to be appreciated that the presence and absence of identical faunas does not necessarily indicate marine connections or their absence. In the Palaeozoic generally and Cambrian particularly the facies also plays an important role in faunal distribution. Three Superregions may broadly be identified, which are American, European and Australo - Asian, the last also includes Antarctic and each of these region include number of small provinces.

When the distribution of Middle and Late Cambrian faunal elements from Kashmir and Spiti are plotted at generic level ( Figs. 16-20 ) on palaeomagnetic map of Scotese et al. (1979),

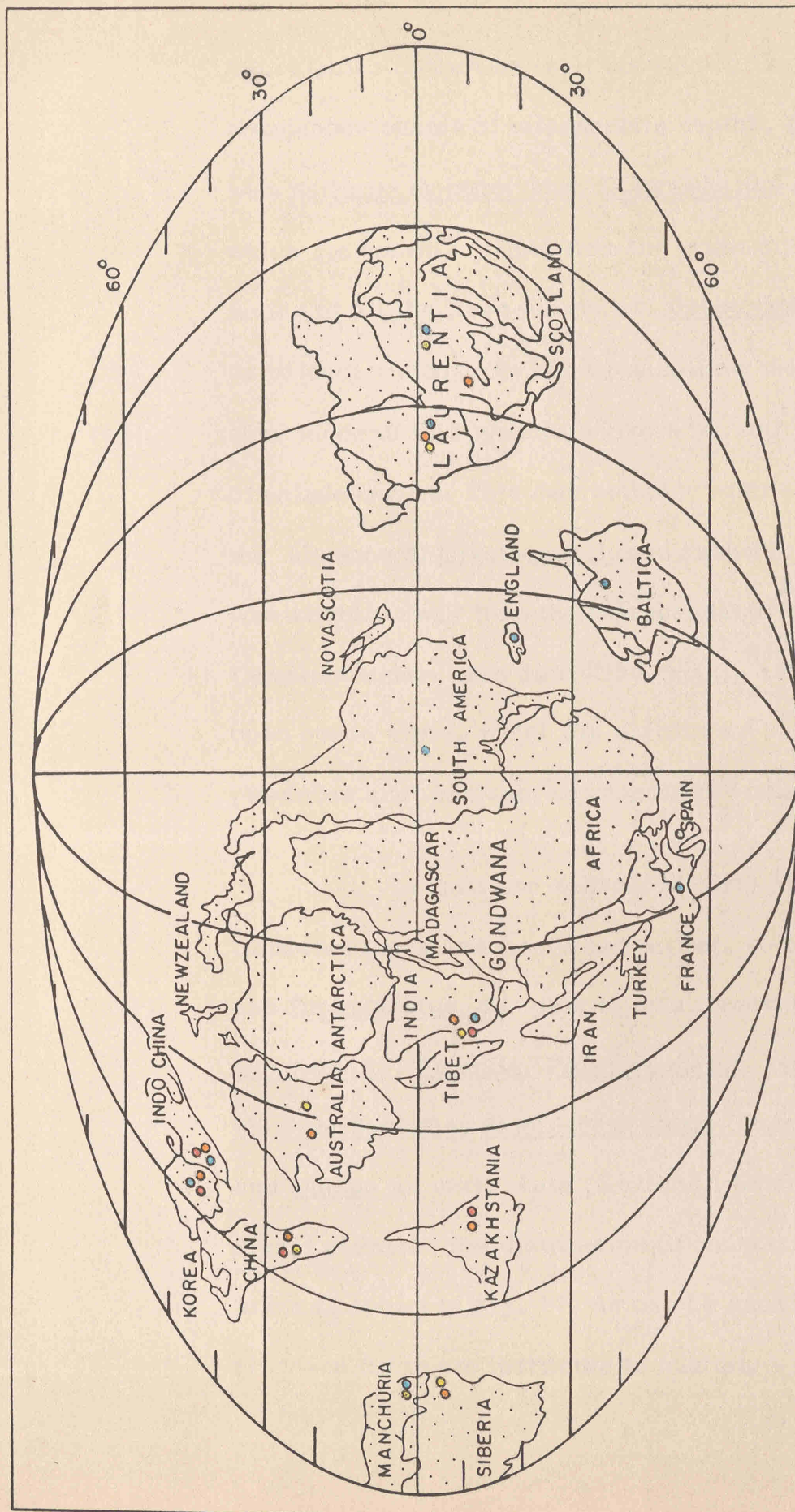
the similarity of fauna between such geographically isolated regions as Himalaya, Siberia, Kazakhstan, parts of Europe and North America, and dissimilarity between Spiti and Kashmir on the other hand can be explained.

The Middle and Late Cambrian fauna can broadly be grouped into four types, based on the factors governing their distribution. These are :

- i) Magnafacies controlled fauna
- ii) Geographically controlled fauna
- iii) Palaeolatitudinally controlled fauna, and
- iv) Cosmopolitan fauna.

Fig. 16 shows the global distribution of middle Middle Cambrian trilobites of Spiti and Kashmir. As is evident from the figure Anomocarella and Anomocaraspis represent geographically controlled fauna, as they are known to occur in the Australo - Asian Province and have not been reported outside this province. Tonkinella, Ptychoparia are reported from India, Iran, Afghanistan, Indo- China, Korea, China, Manchuria and Siberia in Australo - Asian Province and North America, Canada in American Province. The occurrence of these two genera from two distinct provinces can easily be accounted for by

Fig. 16



- Geographically controlled forms      ●
  - Magnafacies controlled forms      ●
  - Palaeolatitudinally controlled forms      ●
  - Cosmopolitan      ●
- Anomocarella, Anomocaraspis
  - [Tonkinella, Ptychoparia, Bailiella, Conocoryphe,
  - Solenopleura, Holocephalina
  - Oryctocephalus
  - Peronopsis, Pagetia

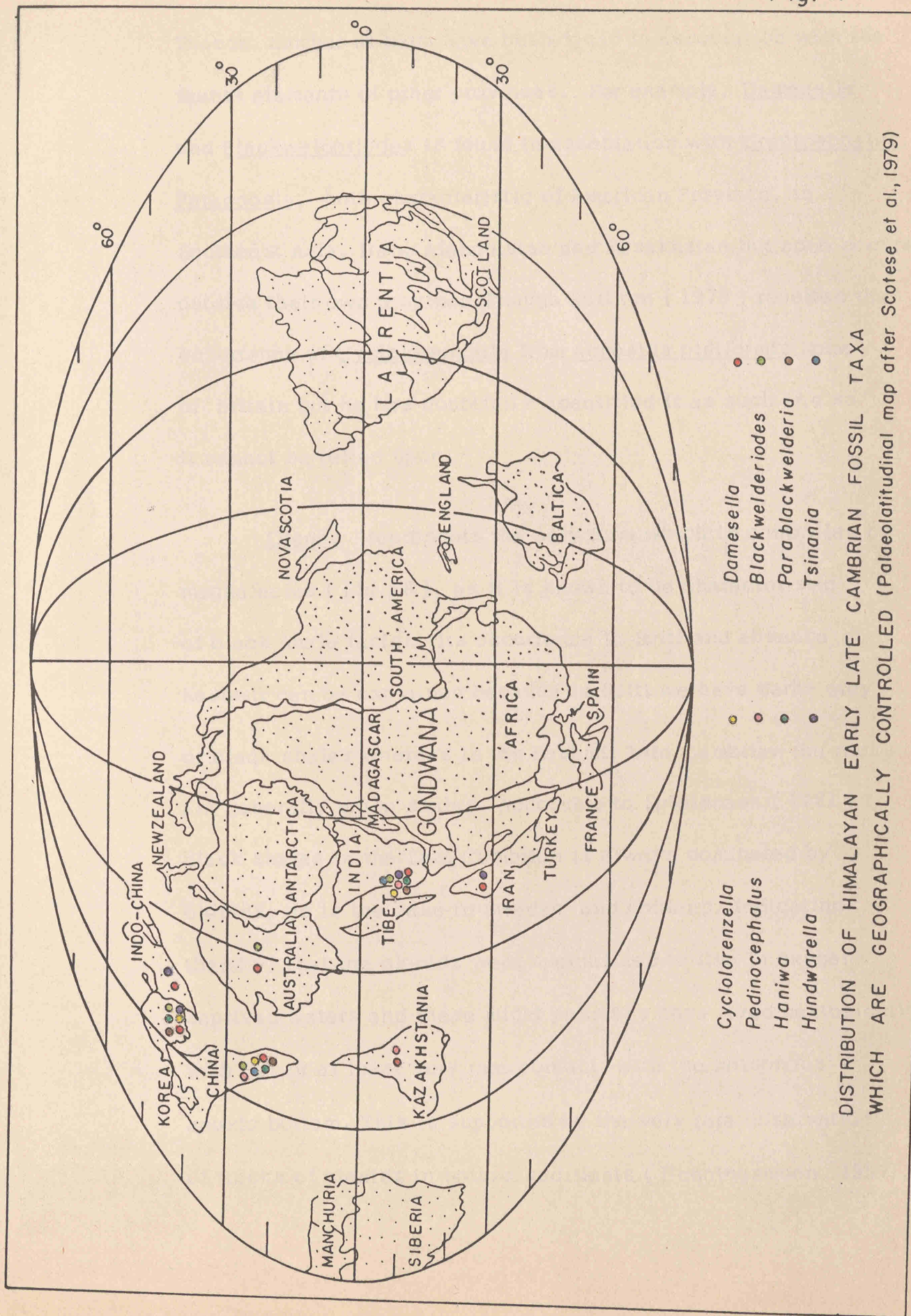
DISTRIBUTION OF HIMALAYAN MIDDLE CAMBRIAN FOSSIL TAXA

(Palaeolatitudinal map after Scotese et al., 1979)

magnafacies control as their occurrence is always from the terrigenous shales of intermediate depths. Same is the case with Bailiella, Conocoryphe, Holocephalina and Solenopleura, which are known to occur from the intermediate and deeper facies of all the three provinces. Oryctocephalus is controlled by palaeolatitudes. As can be seen from the map, not a single occurrence of this genus is known beyond  $20^{\circ}\text{N}$ . and  $10^{\circ}\text{S}$  of palaeoequator. This may probably offer an explanation for the absence of Oryctocephalus in Kashmir, because Kashmir was slightly away from the Palaeoequator than Spiti in Cambrian times. The agnostids Pagetia and Peronopsis are open ocean forms, which are distributed in all the three provinces and represent cosmopolitan fauna.

In Spiti and Kashmir the late Middle and Late Cambrian fauna, as mentioned earlier, comprise Bolaspidella and Diplagnostus for late Middle Cambrian and Cyclolorenzella, Hundwarella, Blountia, Pedinocephalus, Haniwa, Damesella, Blackwelderiodes, Parablackwelderia, Tsinania, Amurticephalus and Olenus for early Late Cambrian (Maentwrogian). Of these faunal elements the distribution of geographically controlled forms is shown in Fig. 17. As can be seen from the figure, all these forms are restricted to Australo - Asian Province.

Fig. 17

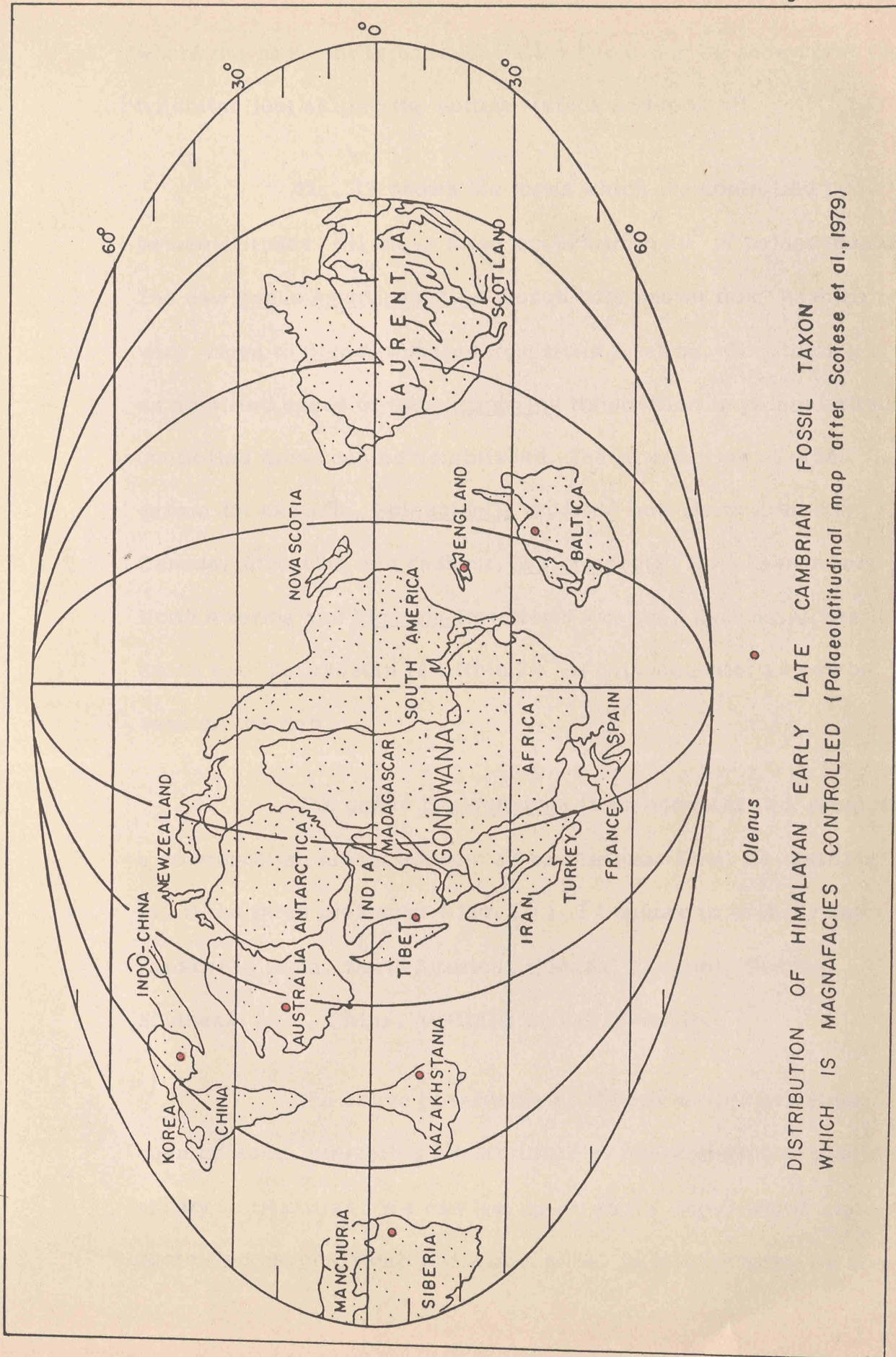


DISTRIBUTION OF HIMALAYAN EARLY LATE CAMBRIAN FOSSIL TAXA WHICH ARE GEOGRAPHICALLY CONTROLLED (Palaeolatitudinal map after Scotese et al., 1979)

Though number of them have been found in association with the faunal elements of other provinces. For example, Damesella and Blackwelderiodes is found in association with Crepicephalus, Paracoosia, both characteristic of American Province, in Southeast Asia, Iran, Afghanistan and Kazakhstan but none occurs outside their own province. Though Rushton ( 1978 ) reported the occurrence of Cyclolorenzella from Agnostus pisiformis Zone of Britain but he has doubtfully identified it as such and so it cannot be relied upon.

Olenus represents the only form which is controlled by magnafacies ( Fig.18 ), as it is known to be characteristic of black shale facies. Its occurrence in Spiti and absence in Kashmir can be explained because in Spiti we have dark- grey or black shales whereas in the Kashmir Late Cambrian the rocks are generally green shales. According to Spjeldnaes ( 1981 ) black shales in the Late Cambrian is always dominated by olenids, as is the case in Sweden and England, indicating thereby, that the olenids were specialised to live in oxygen-deprived waters and these might possibly have lived nektonically with no, or at least very rare contact with the poisonous anoxic bottom. This is supported by the very rare observations of tracks of olenids in bottom sediments ( Henningsmoen, 1957),

Fig. 18



DISTRIBUTION OF HIMALAYAN EARLY LATE CAMBRIAN FOSSIL TAXON WHICH IS MAGNAFACIES CONTROLLED (Palaeolatitudinal map after Scotese et al., 1979)

where the sediment is unusual ( silt ) and it can be shown that the trilobites just skirted the bottom surface and took off.

Fig. 19 shows the forms which are controlled by palaeolatitudes. All these forms occur within  $20^{\circ}$  of palaeoequator. The new genus Amurticephalus though only known from Kashmir is very close to Blandicephalus from North America. Considering it as an allied genus of Blandicephalus its position in palaeolatitudinally controlled fauna can be established. The distribution of other genera for example, Bolaspidella reported from North America, Canada, Argentina and Kashmir, Walcottaspis from Kashmir and North America and Blountia from North America, Kashmir, Australia, China and Kazakhstan is within  $20^{\circ}$  of palaeoequator as can be seen on the map.

The genus Diplagnostus is an agnostid and represents a cosmopolitan faunal element as can be seen from its distribution in all the three provinces ( Fig. 20 ). It occurs in Kashmir and Zaskar in India, North America, Canada, England, Sweden, Southeast Asia, China, Australia and Kazakhstan.

The above observations, though limited in nature, open up some interesting possibilities of interpretation of provinciality in trilobites. We can list up all those forms which are controlled geographically, facies wise, palaeolatitudinally and

Fig. 19

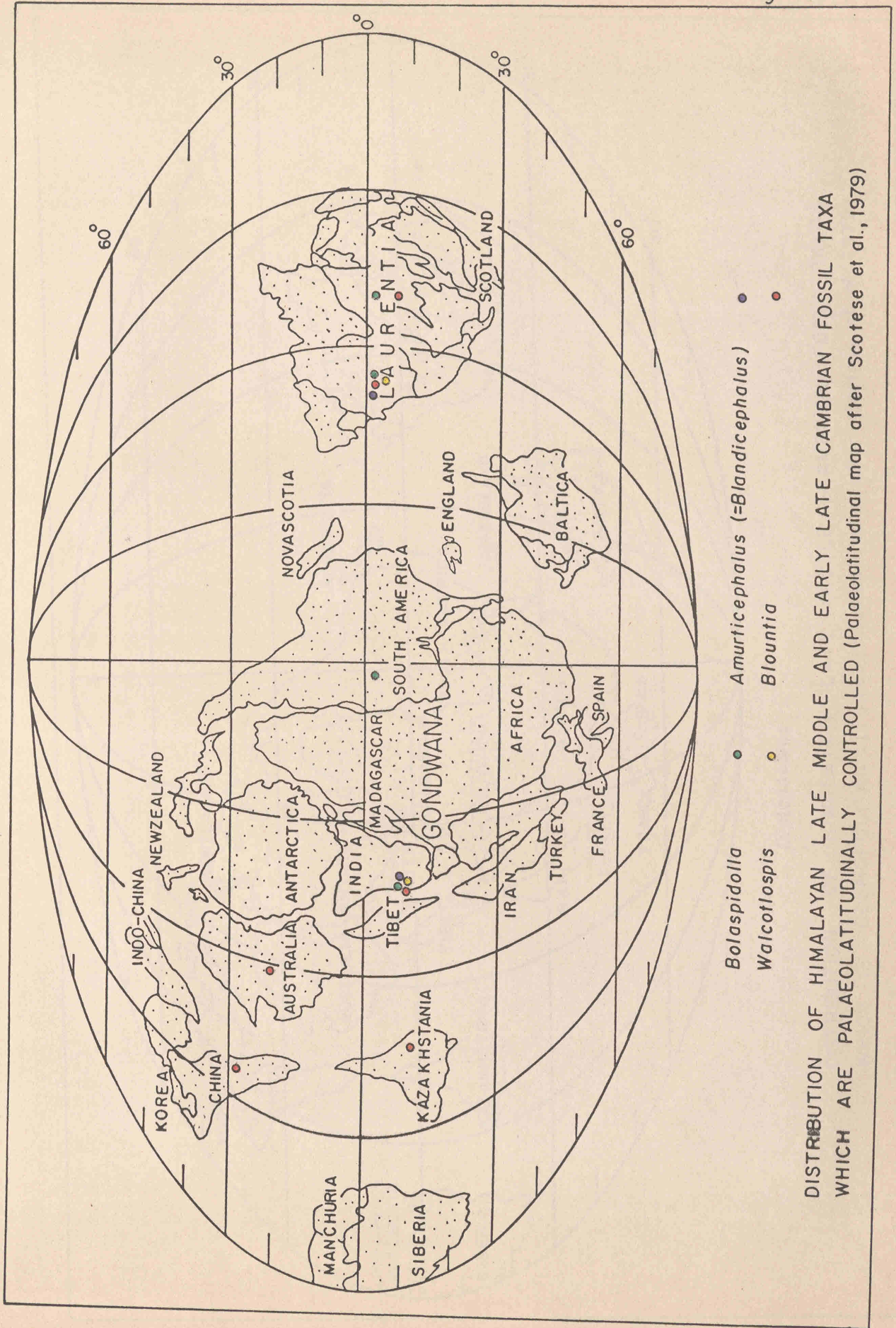
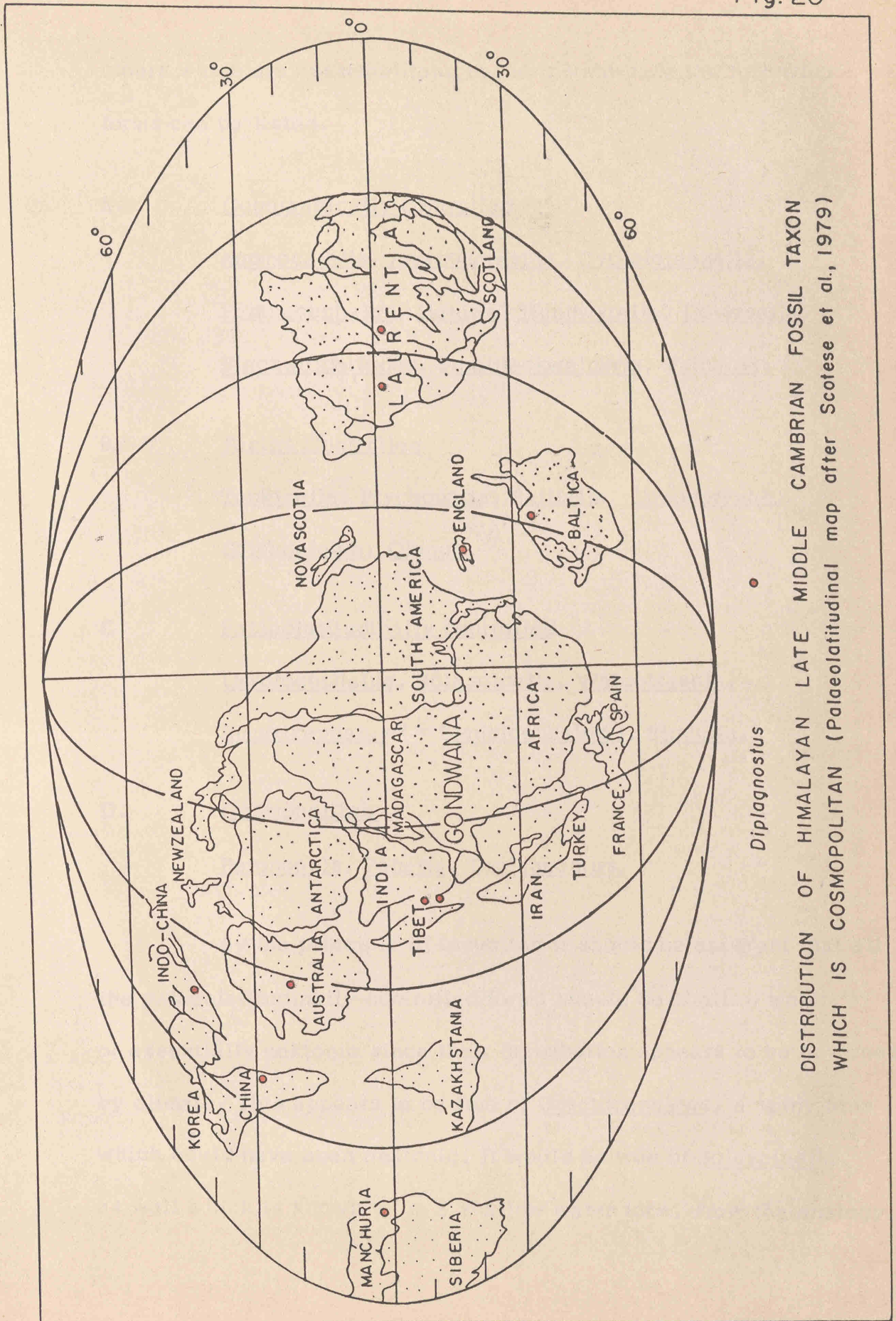


Fig. 20



others which are cosmopolitan. In the instant case the following forms can be listed.

- A.        Geographically controlled  
Anomocarella, Anomocaraspis, Cyclolorenzella,  
Pedinocephalus, Haniwa, Hundwarella, Damesella,  
Blackwelderiodes, Parablackwelderia, Tsinania.
- B.        Facies Controlled  
Tonkinella, Ptychoparia, Bailiella, Conocoryphe,  
Solenopleura, Olenus.
- C.        Palaeolatitudinally controlled  
Oryctocephalus, Bolaspidella, Walcottaspis,  
Amurticephalus ( = Blandicephalus ), Blountia.
- D.        Cosmopolitan  
Peronopsis, Pagetia, Diplagnostus.

By the principle of induction it should be apparent that all the palaeolatitudinally controlled forms should be shallow water or essentially nektonic since their distribution appears to be governed by climate. This appears to be true of Oryctocephalus, a spiny form which could have been nektonic. It would be true of Bolaspidella as well which is known to be a shallow water form. From the analogy

the environment of other forms can be determined.

Likewise the cosmopolitan forms have to be nektonic for a global distribution, which is apparently true of all agnostids but is not true of other polymerids. Some other factors govern their distribution. Facies controlled forms are the most specific since they have a characteristic environment and lithological preference. The geographically controlled forms are the only ones governed by classical concepts of provincialism. A more comprehensive study on the global distribution of all reported trilobite genera and provincialism on the above lines should reveal interesting information about the trilobite distribution in space and time. Such a detailed study is, however, outside the scope of present work.

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PLATE - A

Diplagnostus sp.

- |     |                                |      |
|-----|--------------------------------|------|
| 1.  | Cephalon                       | x 12 |
| 2.  | Cephalon (exfoliated)          | x 9  |
| 3.  | Cephalon (partially preserved) | x 8  |
| 4.  | Cephalon                       | x 10 |
| 5.  | Pygidium (exfoliated)          | x 9  |
| 6.  | Pygidium                       | x 15 |
| 7.  | Pygidium                       | x 14 |
| 8.  | Pygidium (exfoliated)          | x 11 |
| 9.  | Pygidium (exfoliated)          | x 11 |
| 10. | Pygidium                       | x 12 |

Cyclolorenzella sp.

- |     |           |       |
|-----|-----------|-------|
| 12. | Cranidium | x 3.7 |
| 13. | Cranidium | x 3.5 |
| 14. | Cranidium | x 3   |

Walcottaspis sp.

- |     |           |       |
|-----|-----------|-------|
| 15. | Cranidium | x 3.2 |
| 16. | Cranidium | x 3.5 |

Amurticephalus elongatus gen. et sp. nov.

- |     |                        |       |
|-----|------------------------|-------|
| 11. | Cranidium              | x 3.7 |
| 17. | Cranidium              | x 3.5 |
| 18. | Cranidium ( Holotype ) | x 3   |
| 19. | Cranidium              | x 2   |
| 20. | Cranidium              | x 2.3 |

Pedinocephalus kashmirensis sp. nov.

- |     |                        |       |
|-----|------------------------|-------|
| 21. | Cranidium              | x 4   |
| 22. | Cranidium              | x 5   |
| 23. | Cranidium ( Holotype ) | x 3.4 |
| 24. | Cranidium              | x 3   |
| 25. | Cranidium              | x 3.2 |
| 26. | Cranidium              | x 3.5 |

PLATE - A

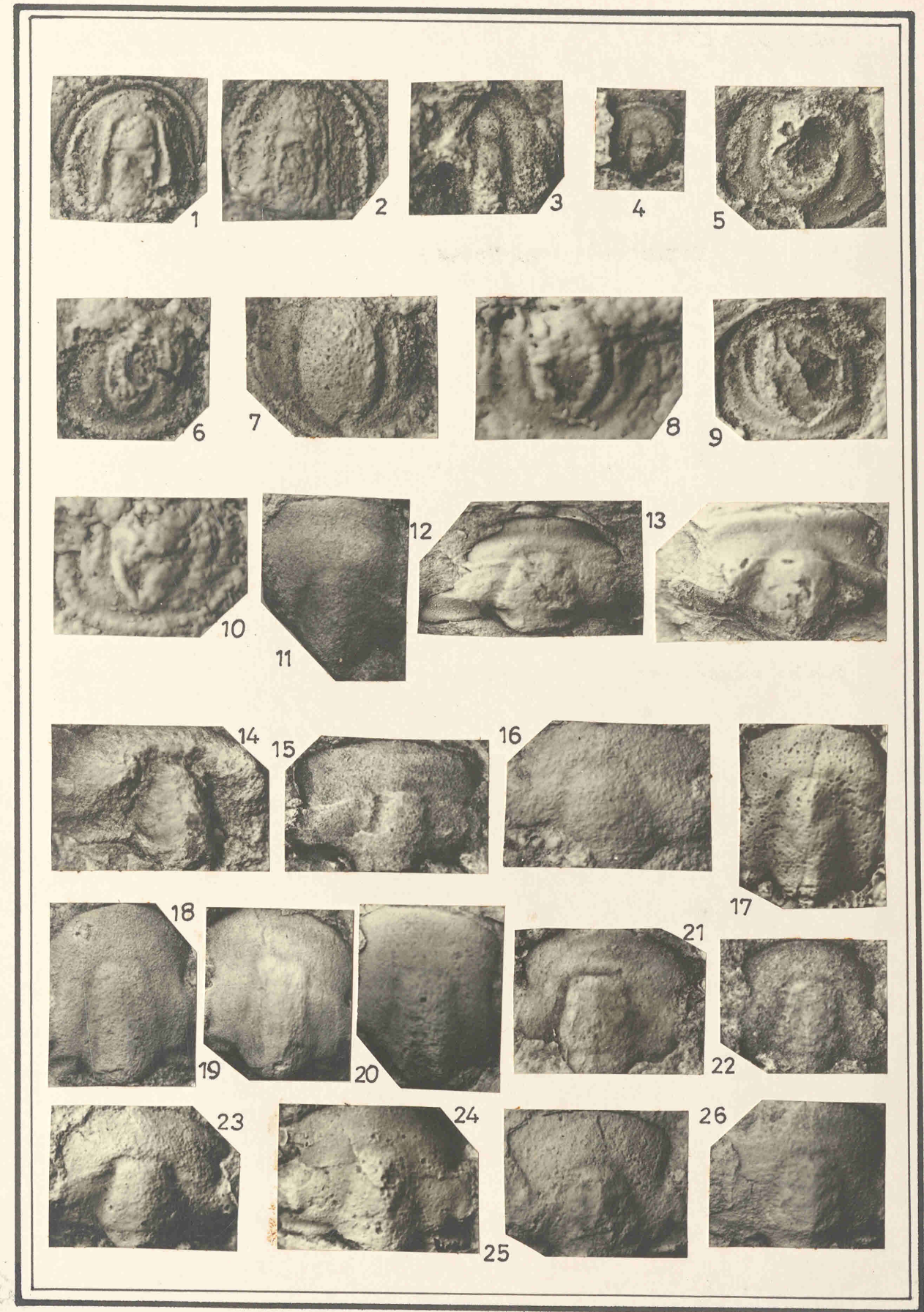


PLATE - B

Olenus haimantensis Reed

- |    |   |   |     |
|----|---|---|-----|
| 1. | Complete exoskeleton                            | x | 4   |
| 2. | Complete exoskeleton                            | x | 4   |
| 3. | Complete exoskeleton                            | x | 3   |
| 4. | Complete exoskeleton                            | x | 4   |
| 5. | Complete exoskeleton                            | x | 4   |
| 6. | Complete exoskeleton without free cheek         | x | 3   |
| 7. | Complete exoskeleton                            | x | 3.5 |
| 8. | Exoskeleton partially broken without free cheek | x | 4   |
| 9. | Complete exoskeleton                            | x | 4   |

Haniwa transversa sp.nov.

- |     |                       |   |     |
|-----|-----------------------|---|-----|
| 10. | Cranidium             | x | 2   |
| 11. | Two cranidia          | x | 2.5 |
| 12. | Cranidium (Holotype ) | x | 2.2 |
| 13. | Two cranidia          | x | 2.4 |
| 14. | Cranidium             | x | 2.5 |
| 15. | Cranidium             | x | 2.5 |

?Anomocarella sp.

- |     |           |   |   |
|-----|-----------|---|---|
| 16. | Cranidium | x | 5 |
|-----|-----------|---|---|

Hundwarella kingi Sudan

- |     |           |   |     |
|-----|-----------|---|-----|
| 17. | Cranidium | x | 2.3 |
| 18. | Cranidium | x | 2   |
| 20. | Cranidium | x | 2   |
| 25. | Cranidium | x | 2.3 |

Hundwarella interpres ( Reed )

- |     |   |   |     |
|-----|---|---|-----|
| 19. | Exoskeleton without free cheek and pygidium | x | 3.3 |
| 21. | Cranidium (partially broken )               | x | 5   |
| 22. | Cranidium with part of thorax               | x | 4.2 |
| 23. | Cranidium with two segments of thorax       | x | 3.7 |
| 24. | Cranidium with little part of thorax        | x | 2.3 |
| 26. | Complete exoskeleton without free cheek     | x | 2.4 |

PLATE - B

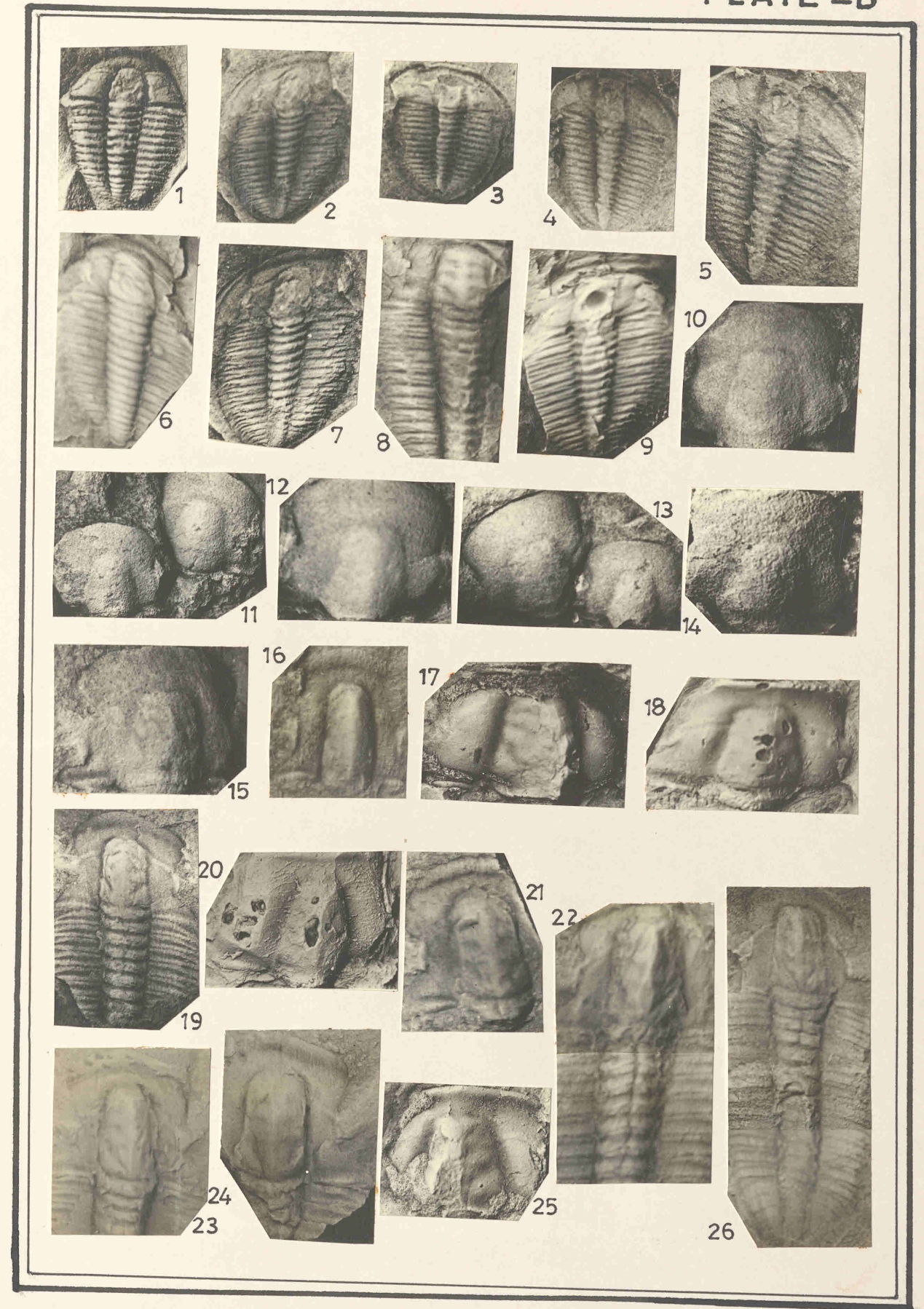


PLATE - C

Hundwarella interpres ( Reed )

2.	Cranidium with a thoracic segment	x	2.6
4.	Cranidium	x	2.2
13.	Cranidium	x	3.7
15.	Cranidium ( partially broken )	x	3.5
20.	Cranidium	x	2.5

Hundwarella rushtoni sp. nov.

1.	Cranidium	x	3
3.	Cranidium	x	4
5.	Cranidium	x	3.5
7.	Cranidium	x	4
8.	Cranidium	x	4.5
9.	Cranidium ( partially broken )	x	3.5
10.	Cranidium	x	5
11.	Exoskeleton without free cheek (Holotype)	x	2.3
12.	Cranidium	x	4
14.	Cranidium	x	5
16.	Cranidium ( partially broken )	x	4.5
17.	Cranidium	x	5.5
18.	Cranidium	x	5
19.	Cranidium with part of thorax	x	3
23.	Cranidium	x	3
24.	Cranidium	x	3.5
25.	Cranidium with two thoracic segments	x	4
26.	Cranidium with a thoracic segment	x	6
27.	Cranidium	x	5
28.	Cranidium	x	4

Spitella barachuda gen. et sp. nov.

6.	Cranidium	x	3.5
21.	Cranidium	x	4.5
22.	Cranidium	x	5

PLATE - C



PLATE - D

*Spitella barachuda* gen. et sp. nov.

- |    |                        |   |     |
|----|------------------------|---|-----|
| 1. | Cranidium              | x | 4.5 |
| 2. | Cranidium              | x | 4   |
| 3. | Cranidium              | x | 4   |
| 4. | Cranidium ( Holotype ) | x | 7   |

*Blountia subangulata* sp. nov.

- |    |                                |   |     |
|----|--------------------------------|---|-----|
| 6. | Three cranidia ( a. Holotype ) | x | 4   |
| 7. | Two cranidia                   | x | 3.5 |
| 9. | Number of cranidia             | x | 2.5 |

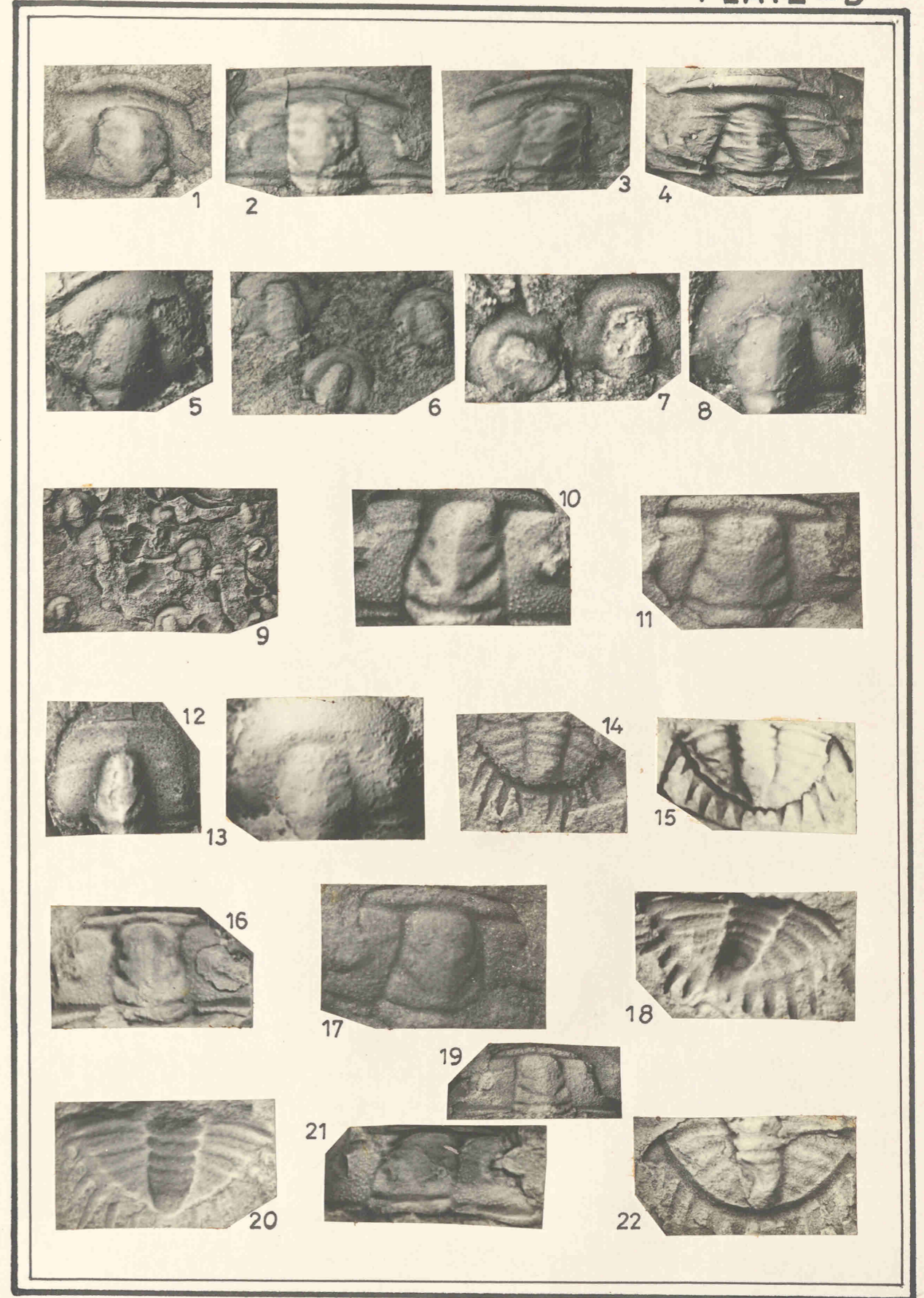
*Blountia* sp.

- |     |                          |   |     |
|-----|--------------------------|---|-----|
| 5.  | Cranidium ( exfoliated ) | x | 3.5 |
| 8.  | Cranidium                | x | 3.2 |
| 12. | Cranidium                | x | 3   |
| 13. | Cranidium                | x | 3   |

*Damesella shergoldi* Shah & Sudan

- |     |           |   |     |
|-----|-----------|---|-----|
| 10. | Cranidium | x | 2.5 |
| 11. | Cranidium | x | 3   |
| 14. | Pygidium  | x | 3   |
| 15. | Pygidium  | x | 1.3 |
| 16. | Cranidium | x | 2   |
| 17. | Cranidium | x | 0.9 |
| 18. | Pygidium  | x | 1.3 |
| 19. | Cranidium | x | 2.5 |
| 20. | Pygidium  | x | 1.3 |
| 21. | Cranidium | x | 0.9 |
| 22. | Pygidium  | x | 1.3 |

PLATE - D



Damesella shergoldi Shah & Sudan

- |     |                              |   |     |
|-----|------------------------------|---|-----|
| 1.  | Cranidium                    | x | 2.3 |
| 2.  | Exoskeleton without pygidium | x | 0.5 |
| 3.  | Pygidium ( cast )            | x | 2.5 |
| 4.  | Pygidium                     | x | 3   |
| 5.  | Cranidium                    | x | 2.5 |
| 6.  | Cranidium                    | x | 2   |
| 7.  | Cranidium                    | x | 2   |
| 8.  | Pygidium ( cast )            | x | 2.5 |
| 11. | Pygidium                     | x | 2   |
| 14. | Pygidium                     | x | 3   |
| 15. | Pygidium                     | x | 3   |
| 18. | Cranidium                    | x | 2   |

Parablackwelderia sp.

- |     |                   |   |     |
|-----|-------------------|---|-----|
| 9.  | Pygidium          | x | 4   |
| 10. | Pygidium ( cast ) | x | 3.5 |

Dictyites sp.

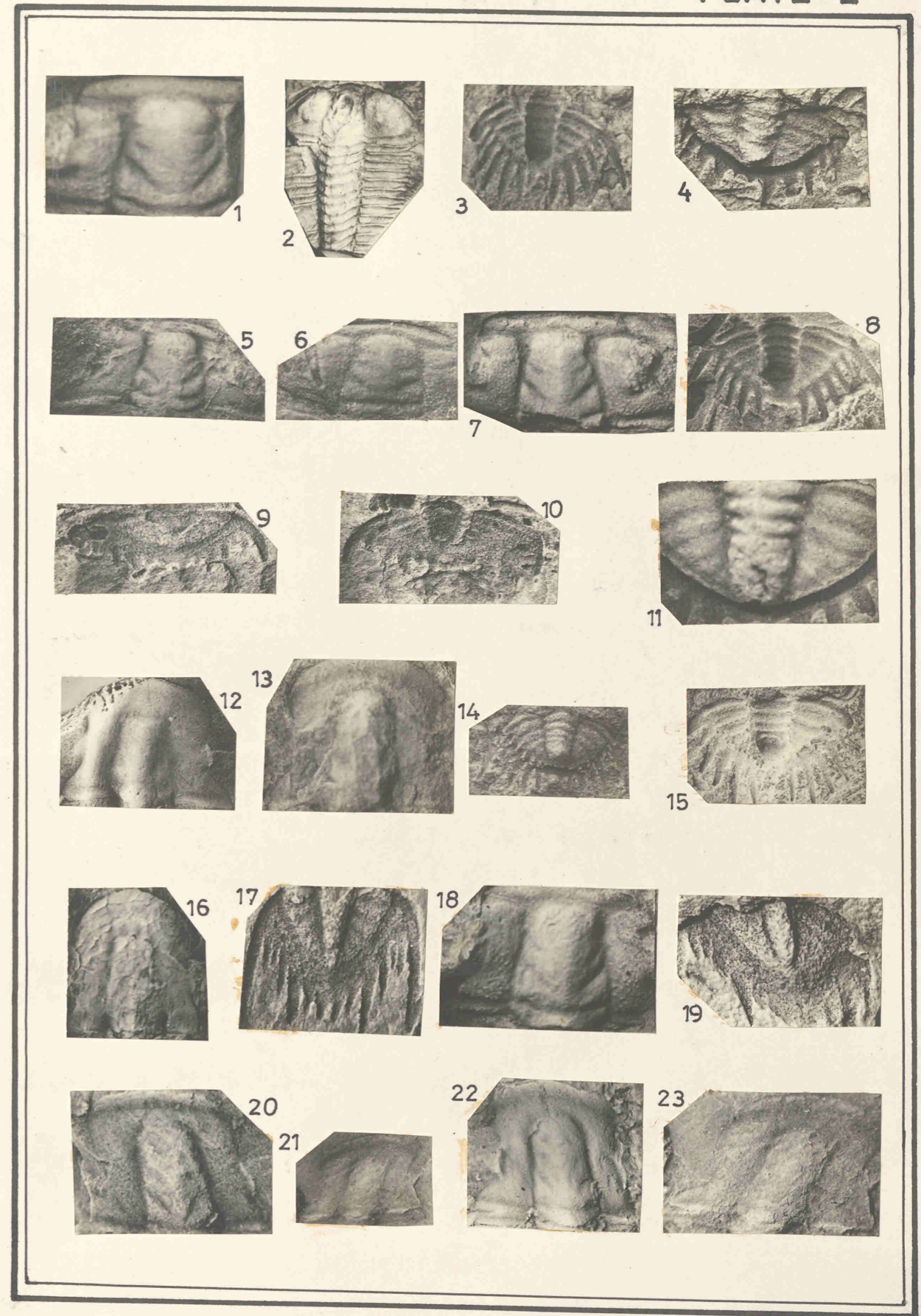
- |     |                          |   |     |
|-----|--------------------------|---|-----|
| 12. | Cranidium                | x | 2.5 |
| 13. | Cranidium ( exfoliated ) | x | 3   |
| 16. | Cranidium                | x | 2.7 |

Blackwelderiodes monkei Húpe

- |     |          |   |   |
|-----|----------|---|---|
| 17. | Pygidium | x | 6 |
| 19. | Pygidium | x | 5 |

Tsinania sp.

- |     |           |   |     |
|-----|-----------|---|-----|
| 20. | Cranidium | x | 5   |
| 21. | Cranidium | x | 4.5 |
| 22. | Cranidium | x | 5   |
| 23. | Cranidium | x | 4   |



		ENGLAND-WALES Rushton, 1974; 1978 Harland et al., 1982	SCANDINAVIA Henningsmoen, 1957 Martinsson, 1974	FRANCE Courtessole, 1973	SPAIN Courtessole, 1973	NORTH AMERICA (EAST) Lochman-Balk & Wilson, 1958, Palmer, 1971	NORTH AMERICA (WEST) Lochman-Balk, 1971, Robison, 1984	SIBERIA Rozova, 1984 Spizharskiy et al., 1984	KAZAKHISTAN Ivshin, 1962 Spizharskiy et al., 1984	AUSTRALIA Opik, 1967, Jago, 1973, 1976	CHINA Sun, 1935 Chang, 1957, 1980	INDOCHINA - KOREA Kobayashi, 1967	AFGHANISTAN Wolfart, 1981	IRAN King, 1955 Kabayashi, 1967 Wolfart, 1981	KASHMIR Shah, 1982 Shah & Sudan, 1983, 1984 Present Work	SPITI Present Work			
		EUROPEAN PROVINCE				AMERICAN PROVINCE			SIBERIAN SUBPROVINCE		AUSTRALO-ASIATIC PROVINCE								
C	A	M E N E V I A N		M A E N T M A G G I A N		L A T E		D O L G E L L I A N		E A R L Y		T R E M A D							
		S O L V A N		P A R A D O X I D E S		B O L E S P I D E L L A		B O L E S P I D E L L A		B O L E S P I D E L L A		B O L E S P I D E L L A		B O L E S P I D E L L A					
C	A	Ptychagnostus gibbus		Triplagnostus gibbus		Eccaparadoxides - Bailiella		Triplagnostus gibbus		Triplagnostus gibbus		Triplagnostus gibbus		Eccaparadoxides - Bailiella		Peronopsis			
		Tomagnostus fissus - Ptychagnostus atavus		Tomagnostus fissus - Ptychagnostus atavus		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Tomagnostus fissus - Paradoxides sacheri		Tomagnostus fissus - Paradoxides sacheri		Bailiella		Bailiella		Mapania	
		Hypagnostus parvifrons		Hypagnostus parvifrons		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus atavus		Ptychagnostus atavus		Bailiella		Bailiella		Eirathia	
		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Goniagnostus nathorsti		Goniagnostus nathorsti		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Solenopleura brachymetopa		Jincella brachymetopa		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Lejopyge laevigata		Lejopyge laevigata		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Agnostus pisiformis		Agnostus pisiformis		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Olenus		Olenus		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Parabolina spinulosa		Parabolina spinulosa		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Protapeltura praecursor		Protapeltura praecursor		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
		Peltura minor		Peltura minor		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia	
Peltura scarabacoides		Peltura scarabacoides		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia			
Acerocare		Acerocare		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia			
Dictyonema fiabelliforme sociale		Dictyonema fiabelliforme sociale		Eccaparadoxides - Bailiella		Eccaparadoxides - Bailiella		Ptychagnostus punctuosus		Ptychagnostus punctuosus		Bailiella		Bailiella		Eirathia			

CORRELATION OF THE MIDDLE - LATE CAMBRIAN SEQUENCE OF THE WORLD

ALOK

