Birbal Sahni
centenary, 1991

Early Permian palaeogeography of the Perigondwana in the Indian segment

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Early Permian diamictite, and marine and non-marine biota link the Perigondwana in the Indian segment with the Peninsula; both belong to the same biological and geographical provinces, though with different lithology and palaeoenvironment. The limits of land and sea changed in the Perigondwana during different stages of the Early Permian. The circum-Gondwanan sea—Kshir Sagar—appears to have been distinct from the Tethys.

THE Gondwana deposits of the Indian Peninsula are fluviatile and overlie the Archaean basement. A few marine intercalations are however seen in the Lower Permian, mostly in the regions along or near the Son–Narmada lineament. These intercalations do not show a continuity, in time, of marine biofacies as seen in the Perigondwana. The Gondwanan deposits in the Indian segment of the Perigondwana developed as two paralic facies, i.e. (i) in the tectonostratigraphic domain of the Lesser Himalaya, unconformably overlying the Precambrian/Cambrian basement, and (ii) further north in the Tethyan domain, either conformably overlying the Upper Carboniferous sediments, or unconformably overlying the Devonian Muth Quartzite (Kumaon).

The Lower Carboniferous formations in the 'Tethyan' Himalaya contain remains of a marine fauna and a land flora. The sediments were deposited in a very shallow and calm environment, in the coastal regions. The region was either subjected to frequent eustatic changes, or to yet undeciphered crustal rises. The depositional gaps in the Carboniferous (Hercynian gap) in the Salt Range, and Kumaon are significant and indicate platform or high relief areas. The Kumaon region possibly had a prolific vegetation during the Carboniferous similar to that known from Spiti and Kashmir. The Salt Range area must have been an extension of Gondwanan India in the post-Cambrian era.

No Carboniferous mega- or micro-flora has so far been reported from peninsular India where a rather large hiatus is seen between the Vindhyan and the Gondwanan sediments. Evidently, this period witnessed platform conditions in the peninsula. If a vegetation flourished in the region during the Carboniferous, and if any portion of that vegetation was ever deposited and preserved, it would have been in the Vindhyan or similar basins and has been irretrievably lost due to later geological activities.

The Lower Permian marine facies of the Perigondwana differs from the Tethyan facies in the absence of the fusuline fauna in the former. In the Lesser Himalaya, the Gondwanan facies developed in the Salt Range, Bhallesh–Chamba, Garhwal, and the East Himalaya. In the Tethyan Himalaya, occurrences of Gondwanan facies are known from Kashmir, Spiti, Kumaon, Nepal and Sikkim. In some regions a certain overlap of the Gondwanan and Tethyan facies is noticed, e.g. in the Salt Range, Karakoram, southern Afghanistan, and northern and eastern Tibet (Table 1).

In the Salt Range (Figure 1), a glacial boulder bed (Tobra Formation, Asselian Stage) that forms the base of the Gondwanan facies unconformably overlies the Cambrian sediments. There is thus a distinct depositional gap indicating prevalence of land conditions, at least for the whole of the Carboniferous. The presence of *Gangamopteris* and *Glossopteris* in the upper part of the Tobra Formation and of palynofossils in its lower part[1] shows existence of terrestrial conditions. The Tobra Formation is succeeded by the Dandot Formation which has an Eurydesma–Conularia fauna of late Asselian–Sakmarian age, widely developed in the

Table 1. Stratigraphical succession in the Early Permian of the Perigondwana.

	SOUTH ARABIA	WEST TETHYAN PROVINCE	PERIGONDWANA TETHYAN PROVINCE								NORTH TETHYAN PROVINCE	LESSER HIMALAYA		PENINSULA
	OMAN	AFGHANISTAN	SALT RANGE	KASHMIR	BHALLESH-CHAMBA	SPITI	KUMAON	NEPAL	SOUTH XIZANG	NORTH SIKKIM	NORTH XIZANG	GARHWAL	EAST HIMALAYA	
KUNGURIAN									QUBUERGA F.		?		?	
ARTINSKIAN	?	ARTINSKIAN	PLANT BED AMB F.	MAMAL F. PANJAL VOLCANIC NISHAT BAGH	PLANT BED BATILE VOLC PLANT BED			PLANT BED ?	CHUBUK F. PLANT BED CURA F.	PLANT BED	?		BHARELI/DAMUDA	GONDWANA
SAKMARIAN	HAUSHI F.	SAKMARIAN	SARDHAI F. WARCHA SST	PYROCLASTIC DIVISION	TRAMAWALA F.	GECHANG MB.	GIRTHI F.	THINGCHU F.	JILONG F.	LACHI F.	ZHANJU F.	BIJNI B.S.		MARINE BED GONDWANA
ASSELIAN	? GLACIAL B.B.	ASSELIAN	DANDOT F. TOBRA F.	DIAMICTITE DIVISION				?					GARU F. RANJIT B.B.	MARINE BED TALCHIR B.B.
U. CARB					?	GANMACHADAM F.								

Non marine Sediments Volcanic; Kshir Sagar Facies; Tethyan Facies; Hiatus

Perigondwana, thus reflecting a marine transgression in the late Asselian. Though the marine conditions continued into the Sakmarian, they were very brief, as is evident from the fluviatile and lacustrine nature of succeeding Warcha and Sardhai formations respectively, which also contain impersistent coal seams and plant remains[1]. Coal is not known from other areas of the Perigondwana as yet. In some places thin fossiliferous limestone beds developed in the uppermost Sardhai Formation and mark another marine cycle which continued into the lower part of the Amb Formation, the brachiopod–bryozoan fauna of which indicates Gondwanan affinity. Layers of *Monodiexodina*, a fusulina of Artinskian age, also indicate a Tethyan affinity. The coexistence of the two facies could only have occurred due to mixing of waters of the Gondwanan Sea (Kshir Sagar[2]) and the Tethys, as well as a brief overlap of Tethyan and Gondwanan facies. The upper part of the Amb Formation is lagoonal and fluviatile in nature and contains elements of the Glossopteris flora. It was followed by a period of non-deposition coinciding with Kungurian and Ufimian stages, before the late Kazanian marine Waragal Limestone of Tethyan affinity was laid.

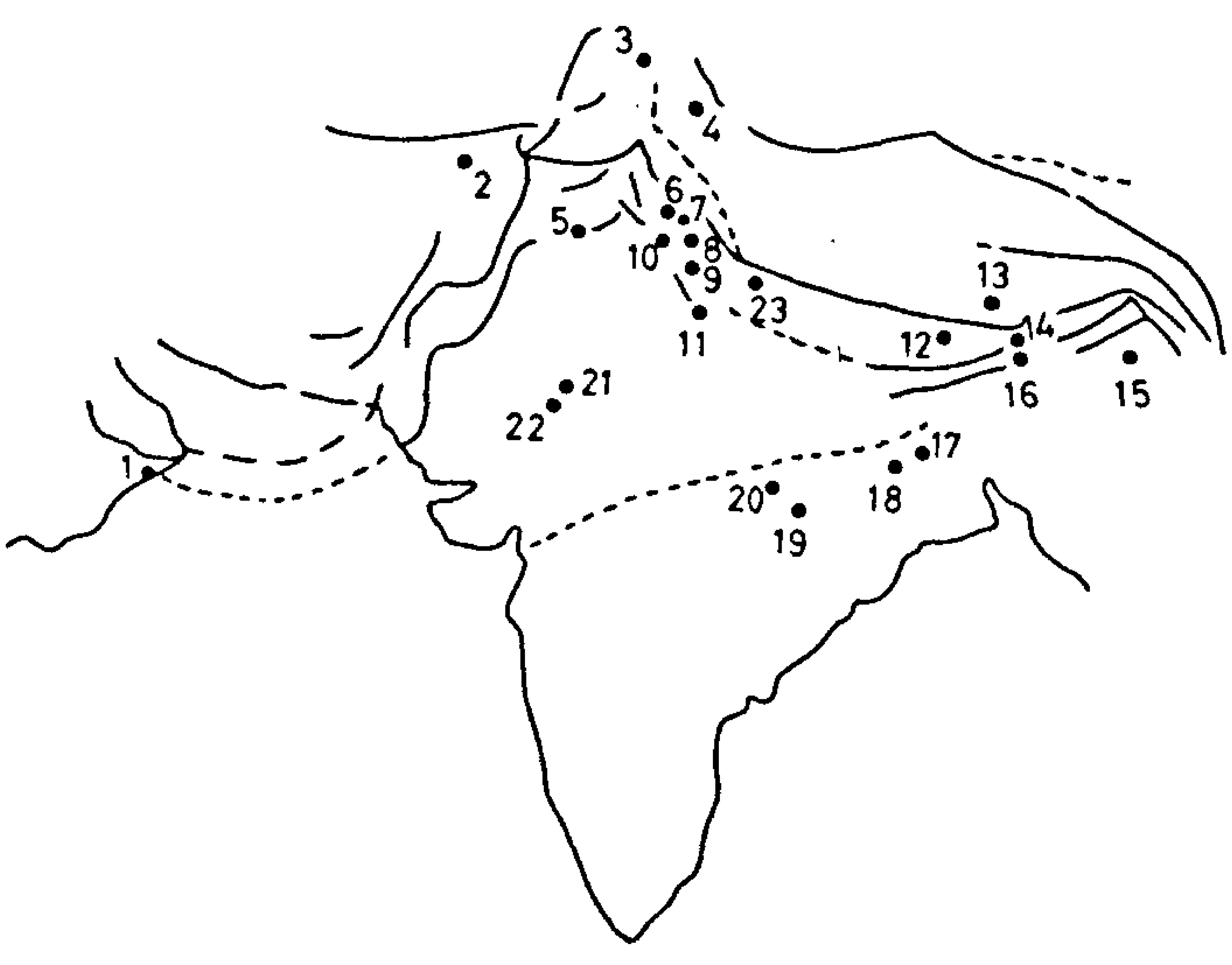

Figure 1. Locations of different basins in the Perigondwana of Indian segment. 1, Oman (South Arabia); 2, Wardak (Afghanistan); 3, Karakoram; 4, Domar (North Xizang); 5, Salt Range; 6, Kashmir; 7, Zanskar; 8, Spiti; 9, Kinnaur; 10, Bhadarwah Chamba; 11, Garhwal; 12, Mount Everest; 13, Lhasa; 14, North Sikkim; 15, Arunachal Pradesh; 16, South Sikkim, 17, Raniganj; 18, Daltonganj; 19, Manendragarh; 20, Umaria; 21, Bap; 22, Badhaura, 23, Kumaon.

In the Kashmir Basin, the Panjal Group, with a fauna and flora of Gondwanan affinity, represents a continuous sedimentation history from Late Carboniferous through Early Permian[3]. The sediments of this group also occur in Pira–Mandi Para-autochthone and Hazara, and are traceable further south in the Bhallesh–Chamba Basin. The marine Agglomeratic Slate, the non-marine Nishatbagh Formation, subaerial and subaqueous Panjal Volcanics, and non-marine Mamal Formation, together comprising the group in an ascending order, deposited due to composite diastrophic changes in the basin[4]. Though terrestrial conditions appeared in the region in early Artinskian, marine influence continued at places up to the early stage of Mamal Formation where lagoonal conditions prevailed, somewhat similar to the Amb Formation.

The Agglomeratic Slate (Late Carboniferous to earliest Permian) is divisible into lower 'diamictite' and upper 'pyroclastic' divisions. It generally overlies the Fenestella Shale with a conformable contact, though the plane of contact varies in different areas, a situation that can develop only in a basin whose bottom is rising. The activation of the sub-crustal magma has possibly been the cause for changes from calm depositional history of the Fenestella Shale to the flyschoid deposits of Agglomeratic Slate mixed with tilloids in the diamictite division: a major change in the depositional environment, including also the influence of the ice-bergs originating from the Salt Range, is indicated. The crustal rise also led to the raising of the water level, covering low-lying areas along the shores, even as far as Afghanistan, Oman, Tibet, and other Himalayan regions.

The biofacies of the lower part of the diamictite division is not different from the underlying Fenestella Shale and shows only a gradual change. The Eurydesma-Deltopecten fauna, a true representative of the Gondwanan facies, makes its first appearance in the upper part of the diamictite division and is followed by the Barren Zone. The pyroclastic division comprises three assemblage zones, collectively referred to as the Stepanoviella fauna of Sakmarian to earliest Artinskian Age.

The Nishatbagh Formation marks the emergence of land conditions in Kashmir, which spread all along Pir Panjal, Bhallesh–Chamba, etc. The formation is composed mainly of tuffaceous slates with some sandstones and varvites in the upper part. Plant fossils recovered include leaves of *Gangamopteris* spp.,? *Glossopteris angustifolia, Noeggerathiopsis* sp. and *Psygmophyllum* spp., most of which frequently occur in the fluviatile deposits of peninsular Gondwana[5,6].

Extensive volcanic activity—the Panjal Volcanics—succeeded the Nishatbagh Formation and covered a vast stretch, possibly as far as Zanskar and Mandi in Himachal Pradesh. The Panjal volcanic activity was intermittent as is evident from the occurrence of a number of intertrappean beds. The intertrappeans mostly comprise tuffs, rarely limestones (marine) or novaculite; flow agglomerates are also found at several levels. Kashmir, thus, must have witnessed a rocky trap environment during this period. The last phase of the volcanic activity took place in different times at different places[7]. These occasionally formed inland freshwater basins in which sediments of the Mamal Formation were deposited.

The basins in Pir Panjal and Para-autochthone areas developed simultaneously with those of the valley, but were possibly not connected. The four plant beds, viz. Vihi, Marahoma, Munda and Mamal, grouped within the Mamal Formation[5], show a younging tendency from west to east that can be recognized by tracing flows in the Liddar and Tral valleys, and other areas.

The lagoonal Vihi bed besides having a fauna comprising fishes and labyrinthodonts, has a flora consisting of *Gangamopteris kashmirensis, Noeggerathiopsis* sp., *Psygmophyllum* sp. and occasional *Vertebraria* and lycopsid remains. *Glossopteris* appears for the first time in the Marahoma bed, in association with *Schizoneura, Sphenophyllum, Sphenopteris*, etc.; *Gangamopteris* starts declining. In the Munda bed of Pir Panjal, the genera *Pecopteris* and *Rhabdotaenia* appear for the first time in the area. The Mamal bed, at the top of the sequence, besides dominant *Glossopteris* interestingly has *Lepidostrobus kashmirensis, Parasphenophyllym* sp., *Lobatannularia* spp., *Rajahia* sp., *Kashmiropteris meyenii* etc.[5,6,8] Some of these elements, e.g. *Lobatannularia* and *Rajahia* are supposed to have a Cathaysian affinity and pose problems of palaeobiogeography.

It is interesting to note that though the plant beds occur at different levels in the Mamal Formation they are always succeeded by the marine Zewan Formation (Tethyan facies) after a para-unconformity (Kungurian–Median), and a strike fault in between. The strike fault is older than the Himalayan folding[9]. The significance of this fault is not clear. The Mamal Formation thus signifies the culmination of the Gondwanan episode in the region.

In the Bhallesh–Chamba Basin (Figure 1), the sequence is similar to that in Kashmir. The basement—Katare-di-Gali Formation[10]—has a lithology similar to that of the Fenestella Shale, but is considered to be older. The lower Permian Tramawala Formation—extension of the Agglomeratic Slate of Kashmir—is mainly tuffaceous in nature and highly fossiliferous. Equivalents of Nishatbagh and Mamal formations in the area are scantily fossiliferous[10,11]. The history of the basin from Early Permian to Early Triassic thus is not different from that in the Tethyan Himalaya and partly can be equated with that of the Salt Range.

In the tectonic Lesser Himalaya, the Bijni Conglomerate Slate of the Garhwal region contains a marine fauna at several levels. The fauna is considered to represent Sakmarian–Artinskian interval[12].

The marine Gechang Member (Kuling Formation) of Gondwanan affinity in Spiti, Lahul and Kinnaur has an Asselian–Sakmarian fauna. In Kumaon, only a very thin calcareous sandstone—Girthi Formation[13]—of Sakmarian age developed. Further east in the Mount Everest region, both marine and nonmarine beds are present[14]. The Jilong Formation contains a Eurydesma and Stepanoviella Fauna, Cura Formation has not yielded any fossils, and the Qubu Formation contains a Glossopteris flora. The Qubu (= Chubuk) Formation is dated as late Early Permian[15], corresponding to the Mamal Formation of Kashmir. Further east in Sikkim, as also in the eastern part of Nepal, the marine Lower Permian sequence continues from the Tethyan Himalaya to the Lesser Himalaya (Lachi Formation and Ranjit Pebble Slate; the latter is supposed to be part of the peninsular Gondwanan sequence).

The Dandot Formation of the Salt Range, Sakmarian and Artinskian beds in Wardak (Afghanistan), marine Haushi Formation overlying glacial beds in

Oman, Jilong Formation in southern Xizang (Tibet), and Zhanju Formation with Stepanoviella fauna in northern Tibet thus constitute a common biofacies province. The Ganmachadam Formation and Gechang Member (Kuling Formation) of Spiti, the Tramawala Formation of Bhallesh–Chamba area, the Girthi Formation of Kumaon, the lower bed of Lachi Formation in the Chumbi Valley of Sikkim, and southern Xizang possibly represent the same province in the Tethyan Himalaya. In the Lesser Himalaya, Bijni Slate of Garhwal, and similar sequences from Nepal to Arunachal Pradesh indicate further southward extension of the same province. In peninsular India, the Lower Permian marine beds of Bap–Bhadaura in Rajasthan, Umaria and Manendragarh in Madhya Pradesh, Daltonganj in Bihar, and Raniganj in West Bengal were possibly laid down in extension of the same sea.

From the distribution of the Late Asselian fauna and the wider spread of the sediments, it can be visualized that a fresh wave of transgression took place in the Early Permian, and the sea that already existed in Kashmir and Spiti spread over to distant areas. Biofacies, lithology, and developmental history show that the Carboniferous and Permian sea of Kashmir (Kshir Sagar) was distinct from the Tethys, and ran along the marginal areas of the Perigondwana. The sea in the Himalayan region was restricted only up to early Artinskian and then regressed, creating land conditions (Table 1).

The Warcha Sandstone and the Sardhai Formation in the Salt Range were deposited as a result of fast change from marine to fluviatile–lacustrine environment. After a brief transgression of the Tethys in the lower Amb, the land conditions again appeared as is seen from remnants of the genera *Gangamopteris* and *Glossopteris*.

In southern Xizang, the marine Jilong Formation likewise passed through Caya Formation to Qubu Formation; the latter contains a flora comprising species of the genera *Sphenophyllum*, *Glossopteris*, *Gangamopteris*, *Raniganjia*, etc. and has a developmental history similar to that of the Salt Range and Kashmir.

The distribution of common biofacies and diamictite in the Early Permian links the Himalayan region with the peninsula, but leaves a spatial gap because of development in linear fashion in most of the Lesser Himalaya, and absence of continental deposits north of the Narmada lineament. The non-marine occurrences in the extra-peninsula are confined to very few localities, south of the Indus Suture, viz. Kashmir, Salt Range, Mount Everest, Nepal and Sikkim (Figure 1). This clearly indicates that land surface appeared in early stages as isolated islands by the retreat of the sea, and then joined the mainland, though only for a short duration, as the area was transgressed by the Tethys in Late Permian.

The Early Permian volcanics of Kashmir, possibly sympathetic to the Carboniferous volcanics of north Ladakh (Karakoram Basin), brought maximum changes in the geography of the region. A terrestrial panorama is inferred for the Salt Range, and parts of Hazara and Para-autochthone areas during the Late Carboniferous. This inference is derived from the geographical distribution of lithofacies. The sea had earlier regressed from Kumaon to Nepal, but Kashmir and Spiti were covered by a very shallow marine basin. Further in the south, in Bhallesh–Chamba, land conditions prevailed; therefore, the shore of the pre-Permian Sea (Kshir Sagar) was not far from the Kashmir Basin (Figure 2,*a*).

In the early Asselian (Figure 2,*b*), the Salt Range continued to have continental conditions, and was encroached by glaciers ushering in very cold conditions. The glaciers opened directly into the sea that existed in Hazara in the north and contributed glacial material to the diamictite division in Hazara and Para-autochthone areas. In course of time, the climate ameliorated, glaciers melted, and vegetation appeared, but for a very short period of time; the area got inundated by the Late Asselian sea. In the Salt Range, the sea-shore was possibly not very far. In Kashmir, this transgression covered a wider tract, as far as Bhallesh and Chamba, and up to Kinnaur in the Spiti region. In the west, the sea reached up to Wardak[14] in Afghanistan, thus encroaching upon the pre-Permian Tethys. The Late Asselian biofacies and equivalent diamictite at present are known only from the eastern part of Lesser Himalaya, and Manendragarh in peninsular India. The Manendragarh marine bed is important because of its occurrence between Archaeans and fluviatile deposits. It was probably a result of opening of a pre-existing Son–Narmada lineament, which made a low relief area for transgression (Figure 2,*c*).

The margin of the land during Asselian in the extrapeninsula thus was slightly south of the Bhallesh Basin on one side and north of Kumaon on the other; further east, south of Mount Everest and passing through eastern Nepal and finally covering part of eastern Himalaya.

During the Sakmarian, the sea level rose further and covered more areas as is evident from the calcareous sandstone (Girthi Formation) with Sakmarian fauna in Kumaon. In the north, the sea reached up to the proximity of Lhasa in Xizang. The Garhwal region of the Lesser Himalaya was too covered by the same sea. It would thus seem that this sea had an east-west extent along the Lesser Himalaya, and was connected with the existing eastern sea – Kshir Sagar (Figure 2,*d*).

Further south, Bhadaura in Rajasthan and Oman in the Saudi Arabian peninsula were also covered by the same sea. The region of Rajasthan may have had the

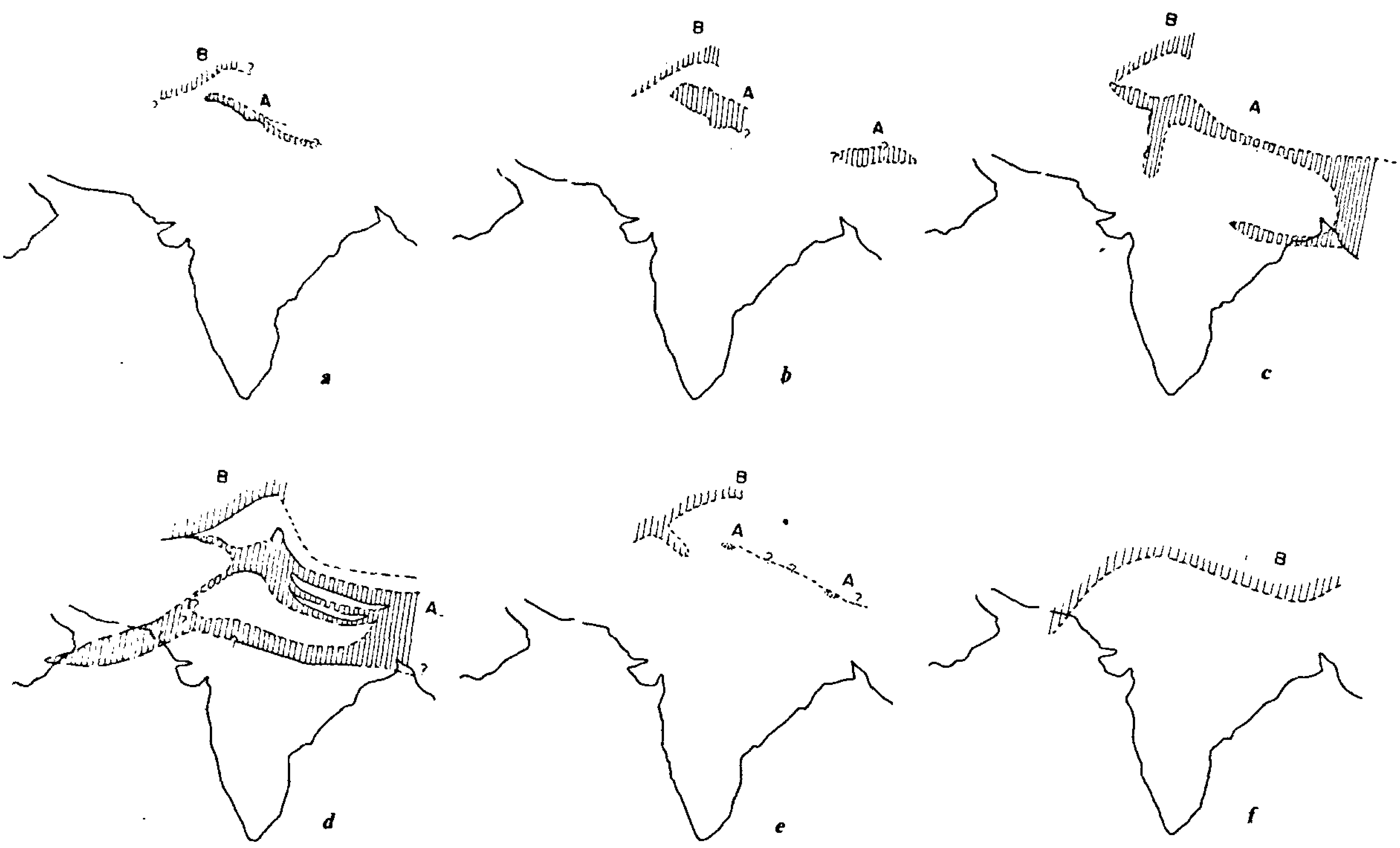

Figure 2. Distribution of land and sea from Late Carboniferous to Early Permian in the Perigondwana of the Indian segment. *a*, Late Carboniferous; *b*, Early Asselian; *c*, Late Asselian (Eurydesma stage); *d*, Sakmarian–Early Artinskian (Stepanoviella stage); *e*, Late Artinskian; *f*, Late Permian Tethys (southern limits), after hiatus of 'Middle' Permian (A, Kshir Sagar; B, Tethys.)

same relief as that of the Kumaon region, but Oman was inundated possibly due to an opening. As supporting evidence one can cite the occurrence of a Late Permian marine bed in Madagascar. The Sakmarian fauna found in isolated patches on the peninsula (Umaria, Daltonganj, Raniganj, etc.) also indicates the existence of an arm of the sea close to the Narmada lineament. Their occurrence between fluviatile deposits indicates oscillating conditions along an older weaker zone that got widened temporarily and for a short duration.

A bellerophon fauna generally dominated the earliest Artinskian sea. The marine conditions were very brief and generally of a regressive nature; convincing records are known only from Kashmir and Bhallesh. In early Artinskian, the Tethys encroached the Salt Range but for a short time. The Salt Range again acquired continental conditions in the later part of the Artinskian. South Afghanistan, however, continued to have marine conditions even later in the Artinskian, but mostly with the Tethyan facies.

Continental conditions appeared earlier in Kashmir (Nishatbagh Formation) and extended as far as Chamba and Pir Panjal area. Small arms of the sea continued at places, but it is difficult to decipher their configuration and connections to the main sea. It is possible that regions of Kashmir and Chamba were part of an island arc or chain and later got connected with the Indian mainland in the south. The region thus had continental conditions for most of the Artinskian; Spiti and Kumaon had already acquired land conditions in the later part of Sakmarian (Figure 2,*e*).

In north Xizang, there is development of marine facies of Gondwanan affinity and that too of Asselian–Sakmarian; the later history connects the region with the northern provinces rather than with the Indian mainland. There is, therefore, a possibility of the presence of a continuous land or islands, west and north of the Kshir Sagar.

The growth and development of Gondwanan facies in the Perigondwana may have some tectonic relationship with the peninsular region. The Gondwanan facies in Afghanistan and north Xizang across the Indus Suture probably represents dissected segments of the eastern Gondwana Supercontinent. These segments possibly separated after Early Artinskian either during regression by slips, or by truncation due to faulting.

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ACKNOWLEDGEMENTS. We thank Dr B. S. Venkatachala for going through the manuscript and making useful suggestions. Dr Usha Bajpai helped with literature.