SYMPOSIUM ON CLIMATIC VICISSITUDES IN INDIA DURING GONDWANA TIMES

(Concluding Remarks by the Chairman of the Symposium held at the First Indian Geophytological Conference, Lucknow, December 21-24, 1975)

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The symposium has brought together evidences regarding climatic vicissitudes in India during Gondwana times from different parameters presented in seven thoughtful articles. The parameters involved have been Palaeogeography (BHARADWAJ, 1976a), Sedimentology (LASKAR & MITRA, 1976 and DUTTA, 1976), Mineralogy (SINGH, 1976), Palaeontology (SHAH, 1976) and Palaeobotany (LELE, 1976 and KAR, 1976).

According to BHARADWAJ, the palaeoposition of South pole as deduced from palaeomagnetic studies changed during the gondwanic time interval resulting into shifts of South latitude for India from 40°—70° during Permo-Carboniferous and Permian, to 30°—60° during Triassic, to 30°—55° during Jurassic and to 10°—50° during Lower Cretaceous. While the climate of India during Gondwana times is principally conditioned by the latitudes she encompassed, BHARADWAJ has also considered the interplay of surface relief and the then continentality of the subcontinent, on the climate. He has concluded the climate of India to have been mostly frigid cold and dry during Permo-Carboniferous, cold or temperate with increased precipitation during Permian, cold and dry or warm temperate and humid during the Triassic, cool or warm temperate and humid during Jurassic and subtropical to warm temperate during Lower Cretaceous.

Sedimentological evidence has been adduced by LASKAR AND MITRA for the climate during Lower Gondwana time and by DUTTA for Upper Gondwana time. During the deposition of Talchir Formation the climate was cold as the sediments represent glacial and periglacial conditions. The Karharbari sedimentation occurred in cold climatic conditions and cool to temperate climate extended probably into the early phase of Barakar sedimentation. During the deposition of younger members of Barakar Formation the climate gradually became warmer humid and equable but not necessarily tropical. During Karharbari and Barakar sedimentation the rich coal deposits indicate damp conditions conducive to prolific vegetal growth. The sediments deposited during the Barren Measures/Iron stone shale/Motur Formation indicate the climate to have been warm humid with seasonal dryness. During the deposition of Raniganj Formation their calcareous nature is deemed to be a product of warm humid climate. LASKAR AND MITRA also argue out that the red bed facies of the Motur Formation are due to its region being lower in palaeolatitude (after DIETZ *et al.*, 1970) than the Godavari, Mahanadi or Damodar basins where the strata corresponding to Motur Formations lacks red colouration.

DUTTA concluded the Mesozoic (Upper Gondwana) climate to have commenced with a warm semi-arid one during which extensive red beds were formed and the same continued till the end of Trias. Then, there was a break in sedimentation and the climate changed to warm humid, similar to the present day tropics, during the Jurassic and Lower Cretaceous.

Singh has synthesized the available mineralogical data from Gondwana strata to conclude upon the climate through Gondwana era. His conclusions, though tentative, but for the older part, indicate a progressive amelioration of the climate from the glacial one during Talchir, cold temperate with impeded drainage and temperate with moderate drainage during older Barakar (=Karharbari Formation) and warm temperate to sub-tropical with moderate to good drainage and tropical humid with excellent drainage during younger Barakar and the same thereafter through Barren Measures with moderate to poor drainage, Raniganj with moderate drainage, Panchet and Mahadeva with seasonal droughts while Rajmahal and Jabalpur with excellent drainage but Umia with good drainage only. The glacial climate during Talchir has been confirmed by SEM studies of quartz grains (Singh, 1974).

Shah has reasoned out with due caution the indications of climate on the basis of faunal evidence. During Talchir deposition the climate is concluded to have been cold to cool. During Karharbari the invertebrate fauna containing small sized *Eurydesma* is reasoned to have lived in cool temperate climate. Faunistic evidence is inconclusive regarding climate during Barakar sedimentation and it is presumed to have been similar to that of Karharbari. The climate of Motur Formation and its equivalents is argued to have been warm and moist and that of Raniganj Formation temperate. The climate during Triassic based upon estheriids and vertebrates is concluded to have been warm moist with seasonal variations. During Jurassic and Early Cretaceous a warm and moist climate has been inferred.

Lele has analysed in detail the megafloral records to conclude on the climatic vicissitudes during Gondwana times. Accordingly the phase of Gangamopteroid foliage with meagreness of pteridophytes during Talchir suggests a cold (glacial) to cool temperate climate. The succeeding phase of Glossopteroid foliage with abundant pteridophytes and gymnospermous woods with growth rings suggests a warm temperate and moist climate with hotter trends later. Commencing at the Permian/Triassic transition, the *Dicroidium* flora with its general poverty and scarcity as well as the presence of xerophytic characters in some forms suggests adverse conditions involving widespread aridity, irregular rainfall and scanty water resources during the Triassic. With the appearance of *Ptilophyllum* flora in Jurassic comprising a rich vegetation of ferns, cycadophytes and conifers which, considering their present climatic needs, seem to reflect a moist temperate to hot climate with marked seasons during Jurassic and Lower Cretaceous.

Kar has discussed the climate during Gondwana era as reflected by the plant micro-remains especially the spores and pollen grains dispersed in sedimentary strata. He has inferred that during Talchir Formation the climate was cold followed by a warming up in Lower Karharbari to turn again cold in the Upper Karharbari time. During Barakar time the climate had turned congenial being warmer and more humid than before. However in the later Barakar time and during the deposition of Barren Measure and equivalent the dearth of pteridophytic spores suggests the climate to have been drier than before. Raniganj Formation time must have had more congenial climate again as pteridophytic spores have been found occurring in good percentage in its sediments. The palynological finds in the Lower Triassic suggest a warm humid climate soon followed by a climate less humid than earlier. The palynoflora known from Lower Jurassic in coastal region seems to indicate less humid climate. In the Upper Jurassic, humidity apparently increased because of more pteridophytic spores having been found than in earlier Jurassic, yet an extreme climate with marked seasonal variations seems to have prevailed.

During Lower Cretaceous the climate was congenial to the cryptogams to flourish

as one of the most important components of the vegetation indicating thereby warmth with good amount of rainfall.

Table 1 sums up comparatively the diverse conclusions on climatic vicissitudes reached on the basis of various parameters as well as conclusions arrived at by the author after a final discussion detailed below.

DISCUSSION

The climate of a region is primarily determined by its latitudinal position. During Gondwana times India remained juxtaposed with eastern Central Africa and Madagascar on the west and Antarctica on the South (BHARADWAJ, 1976a) till the beginning of Jurassic. However, during this period the South pole shifted variedly, thus, changing the latitudinal position of India accordingly. BHARADWAJ (1976b) has reconstructed the position of India with reference to mean positions of the South pole during Permo-Carboniferous, Permian, Triassic and Jurassic times. As the pole shifted, the palaeolatitudes within which India lay, also shifted. However, this shift was not very marked due to the orientation or drift of the land mass or the direction of the polar shift compensating the change to some extent. Thus, between Permo-Carboniferous to Permian and Permian to Triassic only about 10° latitudinal shift each has been conjectured (BHARADWAJ, 1976b). Between Triassic and Jurassic even this was mostly negativated because of the presumed drift of India in the same direction as the migration of the pole. Obviously right upto Jurassic most of India lay higher in the temperate belt. This position and her having formed part of a large continental mass extending West to East, cold to cool temperatures with distinct seasons seem to have been normal. The extent of precipitation appears to have been changing and causing significant difference in the vegetational cover over India. During late Carboniferous to early Permian, the precipitation may not have been much but extensive low lands filled with melted snow-water presumably subtended extensive cold temperate forests. Middle Permian onwards the temperature must have risen to some extent causing replacement of such vegetation as could thrive only in cold temperate regime, by the less cold loving one. The absence of cryptogams from Motur/Barren Measure Formation indicates scanty but seasonal rainfall which alongwith the warmth could only be possible if between the Permo-Carboniferous and Permian pole positions, the pole might have migrated 10° southwards, almost to the position of Triassic pole. This is supported by similarities of sedimentological conditions between the Middle Permian and Middle Triassic. Unfortunately the palaeomagnetic studies leading to the determination of pole position are still not exact and the pole positions used by BHARADWAJ are only near approximations arrived at by computing the mean position from those indicated by different constituent continents. As known so far, the positions of South pole based upon study of Indian rocks of Permo-Carboniferous and Permian age lie much away from the normal polar wander curve and the reason for such an anomaly is still not clear (CREER, 1970). Moreover, CREER (1970) or MCELHINNY (1973) have used the fit of Gondwana continents suggested by SMITH AND HALLAM (1970) envisaging a much northly position for India than argued out by BHARADWAJ (1976a), for deciding the pole position *vis-a-vis* Antarctica. Obviously the possibility of a southward shift of South pole during the Permian as compared to Permo-Carboniferous and Permo-Triassic pole positions, should be likely. If so, the multi-parameter indications of similar climate in the Middle Permian and in the Middle Triassic would be justified.

Although most of the parameters are stated to indicate subtropical to tropical climate for the Triassic and Jurassic, the latitudinal position of India can at the most permit a cool

TABLE 1

Stratigraphic sub-divisions	Palaeo-geography	Sedimentology	Mineralogy	Palaeontology	Palaeo-botany	Palynology	General conclusions
UMIA/VEMAVARAM	Subtrop. humid		Trop. humid Good Drainage			Warm & humid	Subtropical & humid
JABALPUR	Temperate & humid	Warm & humid	Trop. humid Excellent Drainage	Warm & moist	Hot moist to temperate semi-arid	Semi-arid seasonal	Cool to warm temperate & semi-arid
RAJMAHAL			Trop. humid, Excell. to Good Drainage	Warm humid seasonal			Cool to warm temperate & humid, seasonal
MAHADEVA	Cold & Dry to Cool & humid	Warm & semi-arid	Subtropical Seasonal Drought	Warm humid	Increasing aridity	Warm & semi-arid	Cool to warm temperate & semi-arid
PANCHET			Ditto	Warm humid seasonal		Warm & humid	Cool to warm temperate & humid.
RANIGANJ		Warm & humid	Subtrop. to trop. Humid	Temperate		Humid	Cool & humid or semi-arid
BARREN MEASURES		Warm & humid seasonal dry	Ditto	Warm moist	Warm to hot moist temperate	Drier	Cool & semi-arid
BARAKAR	Cold to Cool & humid	Cool & humid	Tropical humid Excell. Drainage	Cool temperate		Cool & humid	Cool & humid
		Cool temperate Cold	Warm temperate to subtrop. Temperate.				
KARHARBARI			Modera. Drainage	Cool temperate		Cold	Cold & humid
TALCHIR		Periglacial	Cold temp. impeded Drainage	Cool to cold	Cool temperate to Cold	Cool	Cool & humid
TALCHIR B. BED	Glacial	Glacial	Cold	Cold		Cold	Cold & dry Glacial

to warm temperate, semi-arid to humid regime with marked seasonal fluctuations. For the Lower Cretaceous most of the parameters are agreed about prevalence of generally warm and all the year round humid climate in India.

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