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Origin of Fining-Upward Cycles in the Early Permian Barakar Formation of Gondwana Basins of Peninsular India

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Abstract

The early Permian Barakar Formation of Gondwana basins of Peninsular India varies from 300-1100 m in thickness. It is composed of fining-upward cycles of conglomerate/very coarse- to coarse- and medium-grained sandstone → interbedded fine-grained sandstone–shale → shale → coal. Among these, some of the fining-upward cycles are relatively thin (6–8 m), containing a greater amount of coarse grade members and laterally impersistent beds of fine clastics and coal. But most of the fining-upward cycles are thick (10–20 m or more) and composed of subequal amounts of coarse and fine grade members. The coal beds at the top of these cycles show sharp lower contact and are laterally persistent for several tens of kilometers. These cycles correspond to deposition under differential subsidence rather than channel migration as suggested by earlier workers. The alternate phases of rapid and slow subsidence of depositional basin through time may account for the development of such fining-upward cycles.

Key-words : Barakar Formation, Peninsular India, Gondwana basin, Fining-upward cycles, Subsidence.

Introduction

The fining-upward cycles are the characteristic features of continental fluvial deposits (Allen, 1965; Cant and Walker, 1978). The early Permian Barakar Formation of the Gondwana basins of Peninsular India is largely considered to be made up of fining-upward cycles, based on a field outcrop study (Casshyap, 1970) and statistical analysis of subsurface logs (Khan and Casshyap, 1981; Tewari and Casshyap, 1983; Casshyap and Tewari, 1984; Tewari, 1997; Hota et al., 2003; Hota and Maejima, 2004). These cycles are represented by conglomerate/pebbly sandstone/very coarse- to coarse- and medium-grained sandstone → fine-grained sandstone–shale → shale → coal from the bottom to top. The coal on the top of fining-upward cycles is overlain by either very coarse- to coarse- and medium-grained sandstone or shale. The origin of Barakar coal-bearing cycles has not been adequately explained as yet. Most workers agreed that the fining-upward cycles may have formed by the lateral shifting of braid bars and (or) migration of associated subenvironments across the flood plain of meandering stream systems (Casshyap and Tewari, 1984; Hota and Maejima, 2004). However, the occurrence of thick and laterally persistent coal facies at the top of Barakar cycles, particularly in the middle and upper parts of the Formation, does not corroborate above generalized interpretation.

The present communication attempts to discuss the origin of Barakar coal-bearing cycles with special reference to those capped by thick and laterally persistent coal facies.

Geological Setting and Lithofacies Characters

In the Peninsular India, Gondwana sediments occur as elongate basins occupying present day river valleys in eastern, eastern-central and south-central India (Fig. 1). Generalized Gondwana stratigraphy is listed in Table 1. The Early Permian Barakar Formation is the most widespread stratigraphic unit of the Gondwana Supergroup of Peninsular India. It is relatively thicker in the type area of the Koel-Damodar valley (800−1100 m) than the Son-Mahanadi (300−750 m) and Pranhita-Godavari (400−600 m) valleys. It shows a variable relationship with underlying formations, lying gradationally above the Karharbari or Talchir and overlaps them to rest directly on the Precambrian basement (Tewari, 2004, 2005). The above overlapping relationship suggests areal expansion of basinal area during Barakar sedimentation following the termination of glacial episode. The Barakar Formation is dominantly composed of interbedded sandstone, shale and coal with lenses of pebbly sandstone and conglomerate in the lower part. Locally, a thick conglomerate horizon (30−40 m) is recorded at the Karharbari/Barakar contact in Talchir and Korba coalfields of Mahanadi valley area (Raja Rao, 1982, 1983). Apart from thickness variations, the Barakar Formation exhibits gross lithological similarity in widely separated Gondwana basins. It has been thoroughly studied for lithofacies, palaeocurrents, depositional models and palaeogeography (Veevers and Tewari, 1995) and attributed to deposition by northwesterly flowing braided

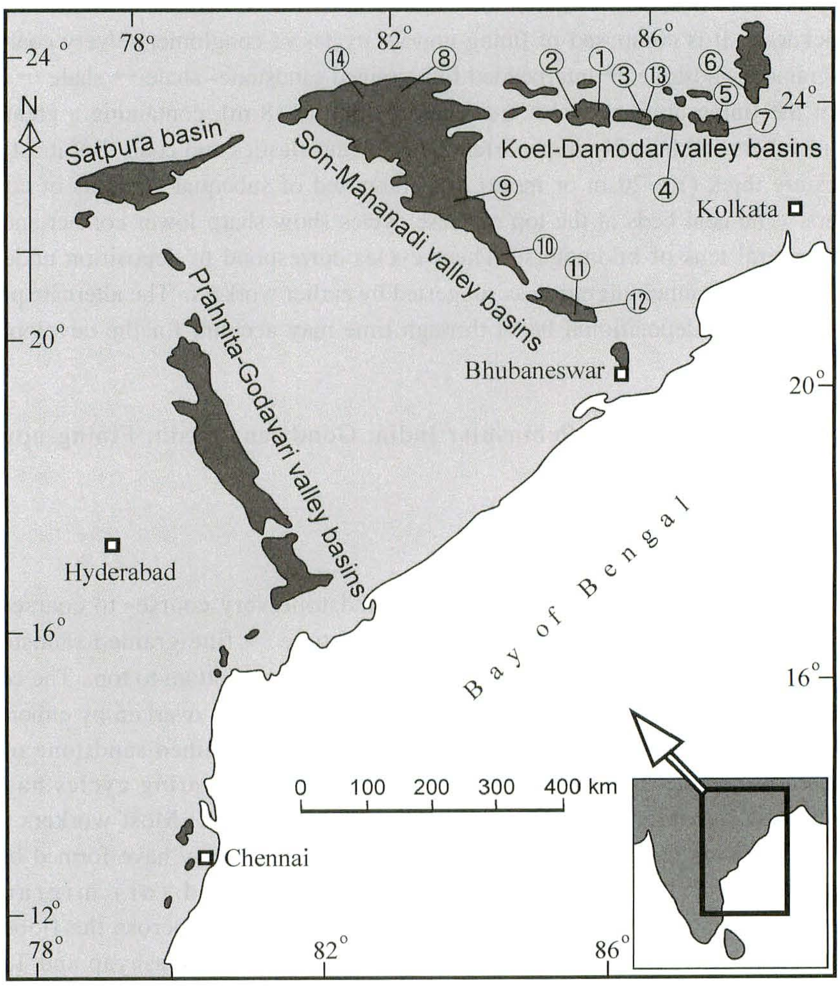

Fig. 1 Distribution of Gondwana basins of Peninsular India. Numbers 1−14 refer to locations of borehole logs shown in Fig. 2.

Table 1 Generalized stratigraphy of Gondwana formations of Peninsular India (modified after Veevers and Tewari, 1995).

Age	Formation
Jurassic	Chikiala Formation Kota Formation Dharmaram Formation Parsora Formation
Triassic	Supra-Panchet Formation Dubrajpur Formation Tiki Formation Maleri Formation Bhimaram Sandstone Yerrapalli Formation Denwa Formation Panchet Formation Upper Pali Formation Pachimarhi Sandstone Upper Kamthi Formation Middle Kamthi Formation
Permian	Raniganj Formation Middle Pali Formation Lower Kamthi Formation Bijori Formation Barren Measures Formation Lower Pali Formation Motur Formation Barakar Formation Karharbari Formation
Permo-Carboniferous	Talchir Formation
Precambrian	

and meandering streams through space and time (Tewari, 2005; Hota et al., 2006). Field studies supported by subsurface logs in different parts of Gondwana basins suggested repetitive occurrence of following lithofacies.

Conglomerate/pebbly to very coarse-grained sandstone

The conglomerate and pebbly sandstone facies forms an important part in the lower Barakar Formation. It occurs as small lens-like as well as moderately thick (2–3.5 m) channel-like bodies. Embedded clasts comprise rounded and well-rounded quartzite of pebble and cobble grades. The facies is generally massive, but faint stratifications and cross beds are seen in places. It has been interpreted as channel lag deposits or longitudinal bar facies (Casshyap and Tewari, 1984; Hota and Maejima, 2004). The very coarse-grained sandstone occurs as channel-like bodies of 2–8 m thick, and show abundant scour-and-fill as well as planar and trough cross-stratified beds. These channel-like bodies have been interpreted as vertical aggradation deposits as well as due to lateral shifting of coarse sandy channel bars (Tewari, 1997).

Coarse- to medium-grained sandstone

The coarse- to medium-grained sandstone shares the bulk of the Barakar Formation in all the Gondwana basins. It occurs as channel to multistory and sheet-like bodies containing large-scale cosets of planar and trough cross-stratified beds. The channel to multistory sandstone bodies have been interpreted as deposits of transverse/linguoid bars of low sinuous streams, whereas sheet-like bodies to lateral accretion in meandering streams (Casshyap and Tewari, 1984).

Fine-grained sandstone, siltstone and shale

The fine-grained sandstone, siltstone and shale facies occurs as interbedded assemblage and exhibits an increase in its proportion from the lower (7–12%) to middle and upper (35–51%) parts of the formation. The fine-grained sandstone is ripple laminated, whereas associated siltstone and shale are parallel laminated. The thin and discontinuous bodies of this facies may correspond to the upper parts of sandy channel bars of low sinuous streams, whereas thick and persistent beds to vertical accretion on stable and extensive overbank (levee) areas of meandering stream channels (Casshyap and Tewari, 1984).

Coal

Coal facies comprises about 8–21% in the lower and 36–53% in the middle and upper parts of the Barakar Formation. It always occurs at the top of fining-upward cycles. The coal seams are relatively thin (< 4 m) and lens-like, and show frequent splitting in the lower part of the Barakar. Thick (4–30 m or more) and laterally persistent coal seams are recorded in the middle and upper Barakar. On the basis of geometry and vertical relationships with associated lithofacies, Casshyap and Tewari (1984, Fig. 17) visualized the evolution of peat swamps in low-lying abandoned flood plains/distal crevasse splays of anastomosing alluvial plains, interchannel areas of meandering rivers, and in protected lakes.

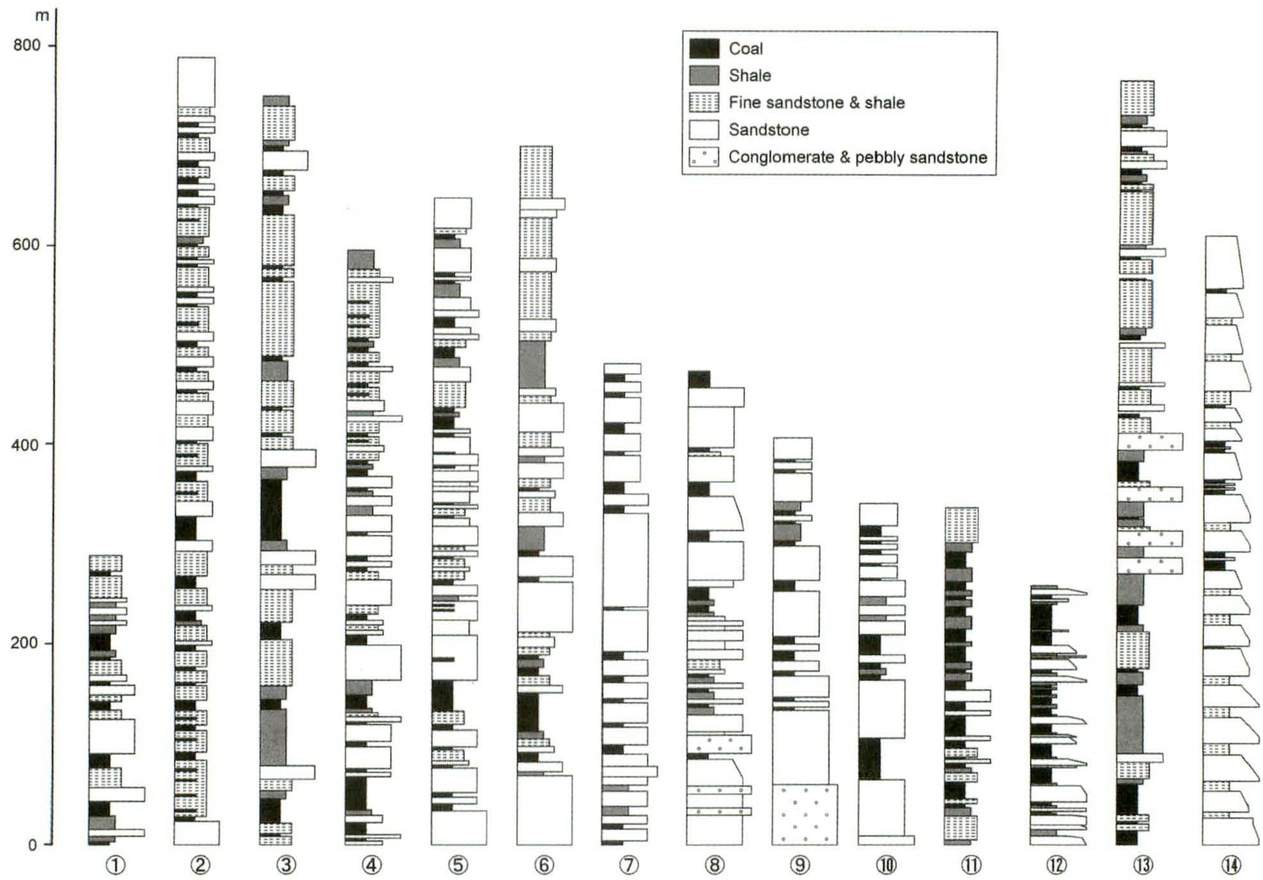

Fig. 2 Representative borehole logs of the Barakar Formation from different parts of basins. Nos. 1−11, 13 and 14, modified after Veevers and Tewari (1995); No. 12, modified after Hota et al. (2003).

Cyclic Characters

As stated earlier, field studies and statistical analysis of subsurface logs have suggested fining-upward cycles in the Barakar Formation of Peninsular India. Representative borehole logs from different parts of the Gondwana basins (Fig. 2) evidently show repetitive occurrence of fining-upward cycles. The complete Barakar cycles are redrawn (Fig. 3), based on Casshyap (1970) and Hota et al. (2003). These Barakar cycles vary in thickness from 7 to 10 m in general. However, the coal-bearing cycles are as thick as 20 m or more in the middle and upper parts of the Barakar Formation (Fig. 2) depending upon the thickness of individual facies. The lower coarse grade member of each cycle is essentially channel-like sandstone bodies showing erosional base. The fragments of underlying coal/carbonaceous shale are commonly found in the lower part of these channel bodies. Most of these channel sandstone bodies are oriented NW−SE in the direction of palaeoslope (Tewari, 1998). The upper parts of fining-upward cycles enclose interbedded fine-grained sandstone/shale (bar top/overbank) and coal (back swamp) at the top. The contact between sandstone and shale is gradational, whereas that of shale and coal is sharp.

Discussion and Conclusions

The various members of fining-upward Barakar cycles represent repetition of channel, overbank and flood plain (lake or swamp) deposits in vertical order. It would imply a gradual decline in current competency from lower to upper part in each Barakar cycle, a common phenomenon of river systems. It is generally believed that these fining-upward cycles are formed by lateral migration of braid bars/meandering channels across the alluvial plain (Casshyap, 1970; Casshyap and Tewari, 1984; Hota et al., 2003; Hota and Maejima, 2004). Indeed, the deposition of channel, overbank and floodplain sediments should represent discrete and independent events of a fluvial system. The accumulation of these lithologic types in alluvial plains corresponds to a differential rate of subsidence of the depositional basin. The very coarse- to coarse- and medium-grained sandstone, occasionally pebbly, filling channel-like bodies may suggest relatively slow subsidence than the overbank fine clastic shale and

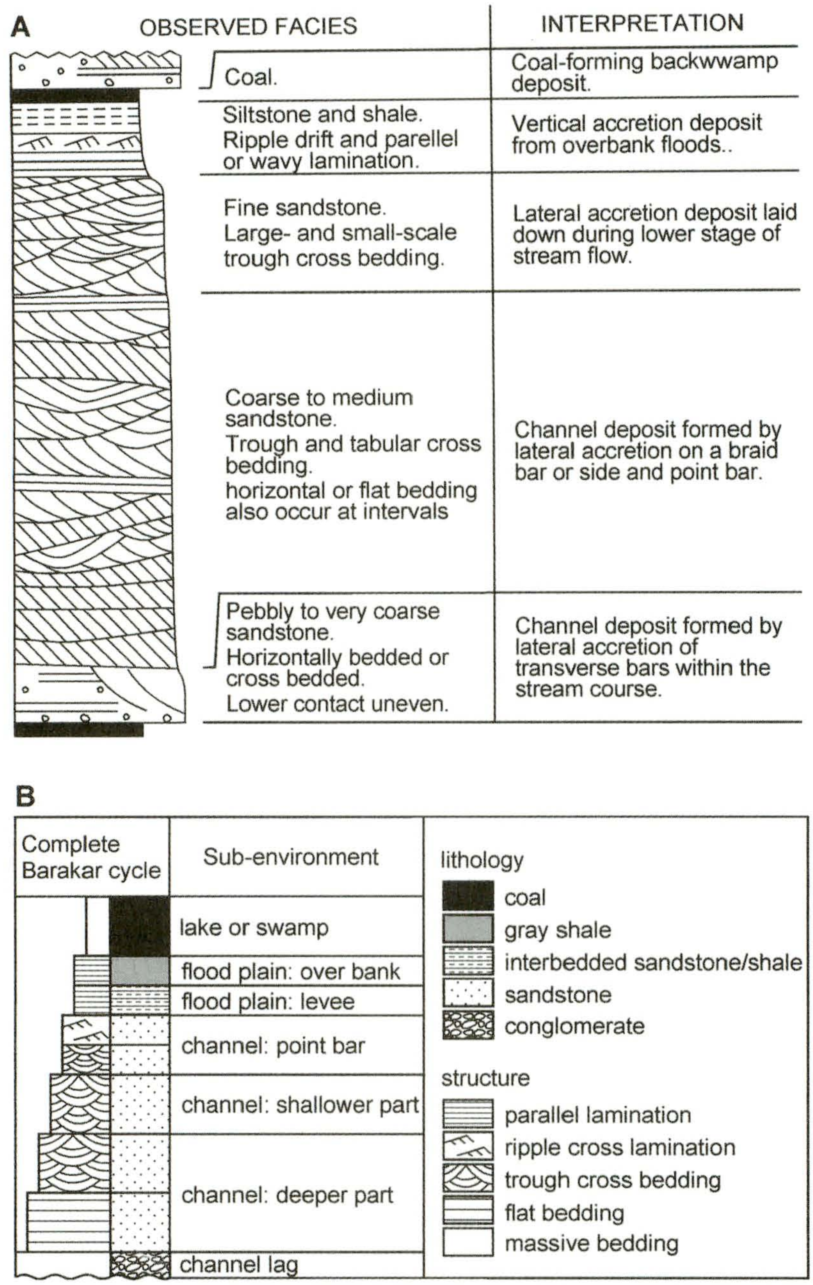

Fig. 3 (A) Idealized standard cycle of the Barakar Formation, based on outcrop study (modified after Casshyap, 1970). (B) Bar diagram showing a complete cycle of the Barakar Formation (modified after Hota et al., 2003).

floodplain deposits.

Channel aggradation and lateral migration of stream channel are widely accepted causes for the development of fining-upward fluvial cycles (Allen, 1965). On the basis of overall thickness of fining-upward cycles and geometry of fine grade member including coal, the Barakar cycles may be of two types. (1) Thin fining-upward cycles of 6−8 m thick with laterally discontinuous fine clastic and coal beds at the top and (2) thick fining-upward cycles (10−20 m or more thick) capped by laterally extensive coal beds. The former type of cycles is fewer in number, confined to the lower part of the Barakar and comprise a great amount of coarse member (about 85%) and subordinate shale and coal. However, the majority of fining-upward cycles in the middle and upper parts belong to the later type. They are composed of subequal amounts of coarse and fine grade members including coal. The former fining-upward cycles may have been developed by channel migration as suggested by several workers. However, the relatively thicker fining-upward cycles with laterally extensive coal seams at the top need to call for alternative explanation. These fining-upward cycles were possibly formed by differential subsidence rather than channel migration. Subsurface geometry of sandstone bodies in parts of the Talchir coalfield does not corroborate channel migration (Hota and Maejima, 2005). In many of the latter type of cycles, the sand bodies of coarse clastic facies are commonly lenticular in geometry and show remarkable incision into the underlying coal seams. Internally the sand bodies reveal multistory, amalgamated channels. These features are highly suggestive of a low accommodation condition, which would have corresponded to relatively slow basin subsidence. On the other hand, fine clastic facies, particularly thick and extensive coal beds indicates aggradation of swamp/shallow lake deposits with keeping a high water table and low energy regime. Such sedimentation style of fines is most likely in a high accommodation condition (Potter et al., 2005; Catuneanu, 2006), possibly reflecting rapid basin subsidence. Differential rate of subsidence of successive facies, therefore, controlled the formation of most of the fining-upward cycles in the Barakar Formation of Gondwana basins of Peninsular India.

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