Plant fossil orientation in Early Permian Barakar Formation of eastern-central India Gondwana basins

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The long axis orientation of plant fossils including *Glossopteris, Gangamopteris* and *Vertebraria* preserved in carbonaceous shale/siltstone lithofacies of Early Permian Barakar Formation from nine coalfields of eastern-central India has been analysed for preferred elongation. The resultant average suggests northeast-southwest trends in Raniganj, Jharia, East Bokaro, North Karanpura, Talchir, Korba and Singrauli coalfields, and east-west in the Saharjuri and Jainti coalfields. The preferred linear trends in the long axis of plant fossils indicate their genetic relationship with the attending flow. It is argued that the plant debris which decomposed to form coal in Early Permian Barakar Formation of eastern-central Gondwana basins was largely of transported or drifted nature. The linear trends of plant fossils are closely comparable to ripple asymmetry, and exhibit oblique or near transverse relationship with the dominant current system. It would imply an angular relation in the deposition of fine clastic and coarse grade lithofacies, respectively. The fine clastic lithofacies of carbonaceous shale/siltstone containing oriented plant fossils is attributed to deposition in overbank subenvironment of the fluvial system.

Key-words—Plant fossils, Early Permian, Barakar Formation, Gondwana (India).

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साराँश

पूर्व–मध्य भारत के गोंडवाना बेसिन के पूर्व पर्मियन युगीन बराकार शैल समूह में पादपाश्म अभिविन्यास

आर.सी.तिवारी

पूर्व मध्य भारत के नौ कोयला क्षेत्रों के पूर्व पर्मियन युगीन बराकार शैल-समूह के शेल/सिल्टस्टोन के लम्बे अभिविन्यास वाले *ग्लॉसोप्टैरिस, गैंगामॉप्टेरिस*एवं *वर्टीब्रेरिया*पादपाश्मों को वरीय दीर्घीकरण हेतु विश्लेषित किया गया है। औसत परिणाम रानीगंज, झरिया, पूर्व बोकारो, उत्तरी करनपुरा तलचीर, कोरबा तथा सिंगरौली कोयला खदानों में उत्तर-पूर्व एवं दक्षिण-पश्चिमी रूझान प्रस्तावित करते हैं, जबकि सहरजुरी एवं जैंती कोयला खदानों में ये पश्चिमी रूझान प्रस्तावित करते हैं। लम्बे अक्ष वाले पादपाश्मों के वरीय रैखिक रूझानों से उनके अनुवर्ती प्रवाह के साथ-साथ आनुवंशिक सहसम्बन्धों का भी पता चलता है। यह तर्क भी प्रस्तुत किया गया कि पादप ध्वंसावशेष जो अपघटित होकर उत्तर पर्मियन बराकार शैल-समूह के पूर्व-मध्य गोंडवाना द्रोणियों में कोयले के रूप में परिणत हो गए, अधिकतर परिवहन अथवा अपसरण प्रकृति के थे। पादपाश्मों के रैखिक रुझान असममित लहरदार चिह्नों से काफी साम्य रखते हैं तथा प्रभावी धारातंत्र के साथ तिर्यक अथवा आसन्न अनुप्रस्थ सम्बन्ध प्रदर्शित करते हैं। यह क्रमशः परिष्कृत खण्डज तथा निकृष्ट कोटि के शैल संलक्षणी निक्षेप में कोणीय सम्बन्ध सूचित करते हैं। कार्बनीकृत शेल/सिल्ट प्रस्तरों के पादपाश्मों का दिक्‌विन्यास परिष्कृत खण्डीय शैल/संलक्षण (सिल्टस्टोन) नदीय तंत्र के अतिसंचित उपवातावरण में निक्षेप के कारण है।

THE Early Permian Barakar Formation of peninsular Gondwana basins of India is characterised by fining upward cycles of (i) very coarse to coarse and medium, occasionally pebbly sandstone; (ii) interbedded fine sandstone-shale, (iii) carbonaceous shale; and (iv) coal (Casshyap, 1970; Casshyap & Tewari, 1984; Tewari & Casshyap, 1983; Tewari, 1997). Among these, the carbonaceous shale lithofacies contains abundant plant fossils of *Glossopteris, Gangamopteris* and *Vertebraria*. The long axis orientation studies of these fossils have not been undertaken so far. The study should be important in understanding the palaeocurrent trends of fine clastic lithofacies in as much as the nature and development of the peat swamps.

In the present study long axis orientation of plant fossils preserved in Early Permian Barakar Formation of various coalfields of eastern and central India are discussed with twin objectives: (i) to reconstruct depositional model of fine clastic lithofacies of Barakar Formation, and its paleoslope, and (ii) to provide criteria for evaluating the nature of plants, drifted or in-situ, which account for the development of peat swamps in Early Permian Barakar Formation.

GEOLOGICAL SETTING

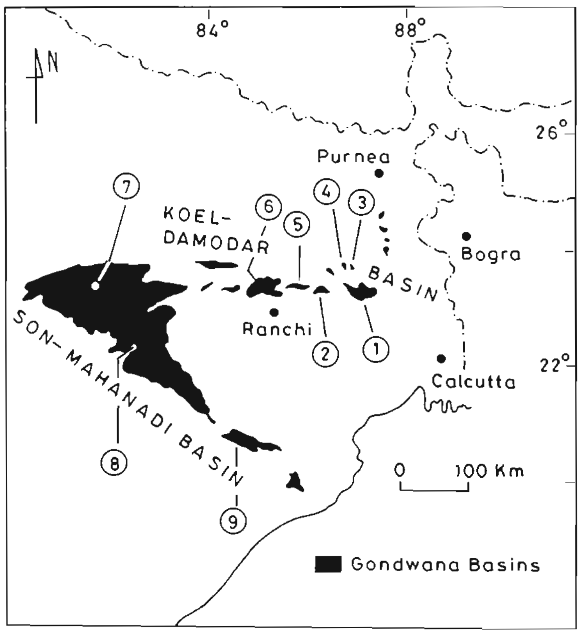
Following the classical synthesis (Pascoe, 1968), the Gondwana geology of Koel-Damodar and Son-Mahanadi Basins of eastern and central India has been reviewed and summarised by several workers (Veevers & Tewari, 1995; Tewari & Casshyap, 1996).

The Early Permian Barakar Formation is extensively developed throughout the eastern-central Gondwana basins, varying in thickness from 600-800 m, which reduces to about 300 m in the western part of Son Valley area. The Barakar Formation rests conformably above the Talchir and or Karharbari, and is conformably overlain by the Barren Measures. Occasionally, the Barakar overlaps the Karharbari and Talchir to lie directly upon Archaean basement. The Barakar Formation which accounts for about 6 to 43 per cent of coal, has been more studied sedimentologically than the underlying and overlying formations. Detailed surface and subsurface studies of Barakar Formation carried out locally in different coalfields and regionally across the Koel-Damodar and Son-Mahanadi basins suggest that, by and large, these sequences were deposited by northwesterly and northerly flowing stream systems (Casshyap, 1973, 1979a, 1979b; Casshyap & Tewari, 1984, 1988; Tewari & Casshyap, 1982; Tewari & Veevers, 1993).

PLANT FOSSIL ORIENTATION

The analysis of preferred orientations in the long axis of plant fossils has not gained much importance in view of the availability of more reliable primary sedimentary structures (Potter & Pettijohn, 1977). The Gondwanan succession of peninsular India, referred to as plant-bearing (Pascoe, 1968), offers opportunity for such studies. These sediments have been thoroughly studied for paleodrainage and paleoslope based largely on cross dip azimuths of cross bedded channel sandstone (Casshyap *et al.*, 1993; Tewari & Veevers, 1993), but the long axis orientation of plant fossils have not been analysed with this view point so far.

The present analysis is based on 2584 long axis measurements of plant fossils which include *Glossopteris*, *Gangamopteris* and *Vertebraria*. The entire data is distributed in 98 outcrops representing 9 coalfields of Koel-Damodar and Son-Mahanadi Basins of eastern and central India (Text-figure 1). The coalfield wise break-up of data is given in Table 1. The fossils included in this study are well preserved and vary in length from 6-12 cm; some are up to 20 cm. The measurements were taken from fairly well-exposed bedding plains of approximately 3 x 3 m size, mainly along the river cuttings and quarry faces. The data was corrected for tectonic tilt wherever regional dip exceeds 10° and grouped in 20° - class intervals to compute relevant statistical parameters at each outcrop, and collectively for different coalfields following



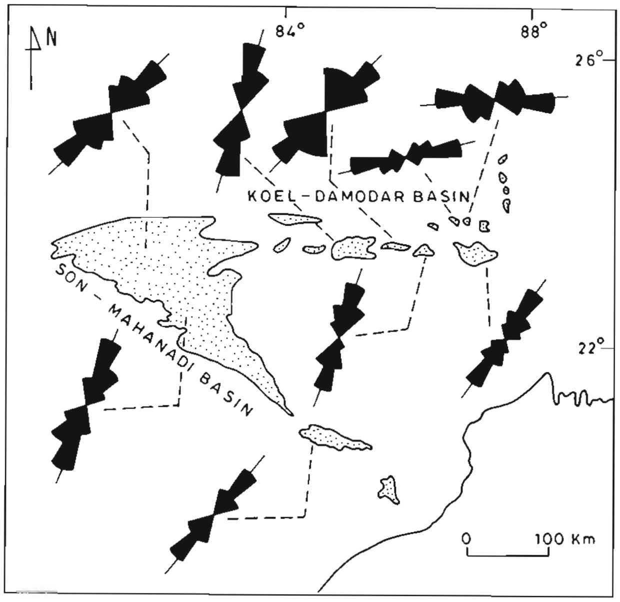
Text-figure 1—Location map of eastern and central India Gondwana basins showing various coalfields under study: 1 - Raniganj; 2 - Jharia; 3 - Jainti; 4 - Saharjuri; 5 - East Bokaro; 6 - North Karanpura; 7 - Singrauli; 8 - Korba; and 9 - Talchir.

conventional procedure (Potter & Pettijohn, 1977).

The grouped data of long axis orientation of plant fossils is unimodal at most of the outcrops suggesting preferred trend. In view of the fairly consistent results at outcrop levels in different coalfields, the data was pooled and analysed separately for each coalfield. The computed average trend is, likewise, unimodal in each coalfield (Text-figure 2) and shows preferred northeast-southwest trends in Raniganj, Jharia, East Bokaro, North Karanpura, Talchir, Korba and Singrauli Coalfields and east-west in the Saharjuri and Jainti Coalfields (Table 1).

Table 1—Average long axis orientation of plant fossils in Early Permian Barakar Formation of various coalfields of eastern and central India

Coalfield	Number of Outcrops	Measurements	Average Orientation	Variance
KOEL-DAMODAR BASIN				
Raniganj	8	280	36°-216°	2309
Jharia	12	356	20°-200°	2147
East Bokaro	6	195	44°-224°	2209
North Karanpura	7	173	16°-196°	1603
Saharjuri	15	343	83°-263°	1808
jainti	9	206	89°-269°	1918
SON-MAHANADI BASIN				
Talchir	18	493	39°-219°	2210
Korba	9	181	21°-201°	1774
Singrauli	14	363	55°-235°	1935

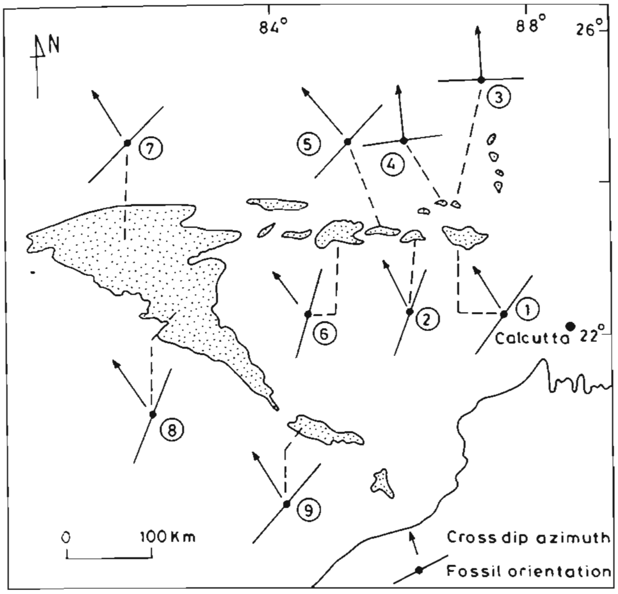


Text-figure 2—Cummulative rore diagrams of long axis orientations of plant fossils from Early Permian Barakar Formation in various coalfields of eastern and central India. Coalfield nomenclature is listed in Text-figure 1.

GEOLOGICAL IMPLICATIONS

The Early Permian Barakar Formation of peninsular Gondwana basins of India has been largely considered to be of fluvial origin. Detailed studies of cross dip azimuths in very coarse to coarse and medium grained channel sandstone bodies show, by and large, northwesterly and northerly paleodrainage and paleoslope during Early Permian sedimentation (Casshyap, 1973, 1979a, 1979b; Casshyap & Tewari, 1984, 1988; Casshyap *et al.*, 1993; Tewari & Casshyap, 1982; Tewari & Veevers 1993).

The unimodal distribution in long axis of plant fossils in different coalfields (Text-figure 2) evidently calls for preferred orientation of fossils in response to attending flow. However, the average trends so deduced exhibit northeast-southwest and east-west to indicate oblique to near transverse relationship of fossil orientation with the average paleoslope obtained from cross dip azimuths in respective areas (Text-figure 3). Similar transverse relationship has been recorded between lee side orientation of asymmetrical ripple marks developed in thin sandstone beds of overbank facies and dominant current system, locally in the Barakar and Barren Measures Formations of Jharia Coalfield (Casshyap, 1979a). The preferred linear trends in plant fossils suggest, beyond doubt, the transportation of plant debris which was responsible for the development and formation of coal in due course of time. Further, there is not much reported presence of upright stems to support in-situ plant growth, except a few local occurrences (Niyogi, 1966). The oblique and (or) near transverse relationship between plant fossil orientation and cross dip azimuths may imply corresponding angular difference in the



Text-figure 3—Diagram showing relationship between average plant fossil orientation and cross dip azimuths in the Early Permian Barakar Formation of eastern and central India. The average cross dip azimuths are after Casshyap and Tewari (1984), except East Bokaro (Khan & Casshyap, 1982) and Jainti and Saharjuri (Tewari & Casshyap, 1982).

deposition of fine and coarse grade members of the Barakar Formation. These coarse grade (very coarse to coarse and medium sandstone) and fine grade (interbedded fine sandstone/siltstone-shale, and shale) have been attributed to lateral accretion/aggradation of traction load inside the main channel, and vertical accretion through suspension in adjoining levees and flood plains (Casshyap & Tewari, 1984). As a rule, the average vector mean of cross dip azimuths developed in channel lithofacies conclusively indicates the direction of prevailing paleoslope. It is therefore argued that while master paleochannels flowed dominantly towards northwest and north during Early Permian Barakar sedimentation, the associated fine clastics were deposited in the adjoining levees and flood plains by subsidiary currents.

CONCLUSIONS

The analysis of long axis orientation of plant fossils preserved in the fine clastic lithofacies of Early Permian Barakar Formation in various coalfields of eastern and central India reveals northeast-southwest and east-west trends. These preferred trends are comparable with ripple asymmetry recorded from overbank facies and show oblique or near transverse relationship with the paleoslope obtained from cross dip azimuths. The present study therefore concludes the following two points.

1. The preferred orientation in the long axis of plant fossils in Early Permian Barakar Formation indicates drifted/transported nature of plant debris as against the *in-situ* plant growth.
2. The angular relationship of plant fossil orientation with the regional paleoslope imply the deposition of fine clastic lithofacies in the overbank and flood plains subenvironments.

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