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Biomarker signatures of Permian Gondwana coals from India and their palaeobotanical significance

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ABSTRACT

Coal samples belonging to the Lower Permian Barakar Formation and the Upper Permian Raniganj Formation, collected from Damodar Valley Basin of eastern India, have been analysed for understanding their organic geochemical characteristics using Rock-Eval pyrolysis, gas chromatography–mass spectrometry (GC–MS) and comprehensive two-dimensional gas chromatography coupled with time-of-flight mass spectrometry (GC×GC-TOFMS). The Rock-Eval pyrolysis parameters suggest that the coals from both the formations contain a mixture of Type-II and Type-III kerogen. The Rock-Eval T_{max} values of the analysed coals vary from 417 to 451 °C. *n*-Alkanes ranging from C_{12} to C_{31} predominate the aliphatic hydrocarbons present in the coal extracts. The carbon preference indices (CPI) as well as the odd-to-even preference (OEP) values of the *n*-alkanes are >1, suggesting input from higher vascular land plants. C_{29} Steranes predominate over C_{27} and C_{28} steranes, which corroborates contribution from terrestrial higher plants. Aliphatic diterpanes like *ent*-beyerane, isopimarane, abietane, phyllocladanes and *ent*-kaurane as well as aromatic diterpanes like simonellite, bisnorsimonellite, retene, methylretenes and tetrahydroretene which are mainly known to originate from conifers are detected in the studied coals. The Lower Gondwana floral assemblage of Peninsular India is mainly represented by Glossopteris flora (Pteridospermatophyta). However, some primitive conifers have also been reported from this succession. We propose that the diterpanes detected in the studied coals were possibly derived from the primitive conifers. This implies that the biosynthetic pathways to produce these diterpanes had evolved in the Gondwana flora during the Permian period.

1. Introduction

The Gondwana Basins of India are the chief coal producers of the country and they host about 98 to 99% of India's total coal reserves (Singh, 1995; Mukhopadhyay et al., 2010). The economic significance of these basins have attracted many researchers, as a result, extensive studies have been carried out on their origin, stratigraphy, sedimentation pattern, tectonic settings, depositional environment and palaeogeography (e.g., Casshyap and Tewari, 1984, 1987, 2001; Bhattacharya et al., 2004; Bhattacharya and Bhattacharya, 2007; Tewari and Maejima, 2010). The main coal producing formations are the Lower Permian Barakar Formation and the Upper Permian Raniganj Formation, separated by a non-coal bearing Middle Permian Barren Measures Formation. The Lower Permian coals are more extensive than the Upper Permian coals (Dutta, 2002; Mukhopadhyay et al., 2010). The plant fossil records of the Lower Gondwana coals and sediments suggest that they were dominated by Glossopteris flora.

Biomarkers, also known as geochemical fossils are molecular organic compounds present in crude oils, coals and sediments. These compounds are derived from specific biological precursors and therefore convey information about the source of organic matter and depositional environment. Biomarker analysis is widely applied in palaeobotanical and palaeoenvironmental studies (e.g., Paul et al., 2015; Bhattacharya and Dutta, 2015). Studies based on the application of biomarker distributions for reconstruction of palaeoenvironment and palaeovegetation of the Permian Gondwana coals include studies on Parana Basin coals, Brazil (da Costa et al., 2014); Sydney Basin coals, Australia (Izart et al., 2015) and South African coals (Fabiańska and Kruszewska, 2003). However, a detailed biomarker study of the Indian Gondwana coals has not been carried out so far.

The present study attempts for the first time a detailed documentation of biomarker distribution in the Lower Permian and the Upper

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Table 1
Generalized stratigraphic succession of Gondwana sediments in Damodar Valley Basin, eastern India (after Bhattacharya et al., 2004).

Lower Cretaceous		Lamprophyre and dolerite intrusive	
Jurassic	Upper	Non-deposition	
	Middle		
	Lower		
Triassic	Upper	Supra-Panchet unit	
		Infra-Norian erosional surface	
	Lower	Panchet Formation	
Permian	Upper	Damuda Group	Raniganj Formation
			Barren Measures Formation
	Lower		Barakar Formation
			Karharbari Formation
		Talchir Formation	
Upper Carboniferous			

Permian coals from Damodar Valley Basin. The main objective of this study is to understand and compare the palaeobotanical precursors of the organic matter in the Lower Permian and the Upper Permian coals from molecular organic-geochemical parameters.

2. Regional geology and stratigraphy

The Gondwana group of basins of India are intra-cratonic basins which occur along rifted grabens (Biswas, 1999). Approximately 5.5 km thick Gondwana sediments, mainly of fluviatile/lacustrine origin were deposited from Upper Carboniferous to Lower Cretaceous and are preserved in the linear rift basins (Tewari, 2005; Tewari and Maejima, 2010). The Damodar Valley Gondwana Basin of eastern India consists of a sequence of east-west aligned sub-basins. The generalized stratigraphic succession of the Damodar Valley Basin is presented in Table 1. The coal samples used for this study were collected from the Raniganj, West Bokaro and South Karanpura sub-basins of the Damodar Valley Basin (Fig. 1).

The southern part of the Karnapura Sub-basin is named as the South Karanpura Sub-basin. This sub-basin lies between 23°38′- 23°45′ N latitudes and 85°05′- 85°28′ E longitudes in the Ramgarh district of Jharkhand and covers about 194 km^2 area (Murthy et al., 2014). The West Bokaro Sub-basin is the western half of the Bokaro Sub-basin. This sub-basin lies between 23°44′- 23°50′30″ N latitudes and 85°24′-85°44′30″ E longitudes in the Hazaribagh district of Jharkhand and extends over an area of 207 km^2. The Raniganj Sub-basin is the eastern most sub-basin of the Damodar Valley Basin. The Raniganj Sub-basin is an elongated, semi-elliptical basin which covers approximately 3000 km^2 area (Ghosh, 2002). It is located between 23°03′- 23°51′ N latitudes, and 86°42′- 87°28′ E longitudes in the Burdwan district of West Bengal.

The Lower Permian Barakar Formation comprises of conglomerate, sandstone, siltstone, carbonaceous shale, and coal (Veevers and Tewari, 1995). The Barakar coals were deposited in protected peat swamps in flood plains and confined lakes of meandering streams (Casshyap and Tewari, 1987). The coal deposits are thick and laterally continuous (Casshyap and Tewari, 1987). The Barakar Formation is followed gradationally by the Barren Measures Formation which is devoid of economically exploitable coal seams. The Raniganj Formation deposited gradationally over the Barren Measures Formation and consists of sandstone, carbonaceous shale, and coal (Casshyap and Kumar, 1987). This formation is more widely developed in the Raniganj Sub-basin and attains a thickness of 1035 m (Casshyap and Kumar, 1987). The coal seams are thin to moderately thick with an average thickness of 0.5–6.5 m in the Raniganj Sub-basin.

3. Samples and methods

3.1. Sample collection

A total of eighteen coal samples were collected for this study. Four core samples of Barakar coal from the West Bokaro Sub-basin and nine samples of Barakar coal from a mine-section in the South

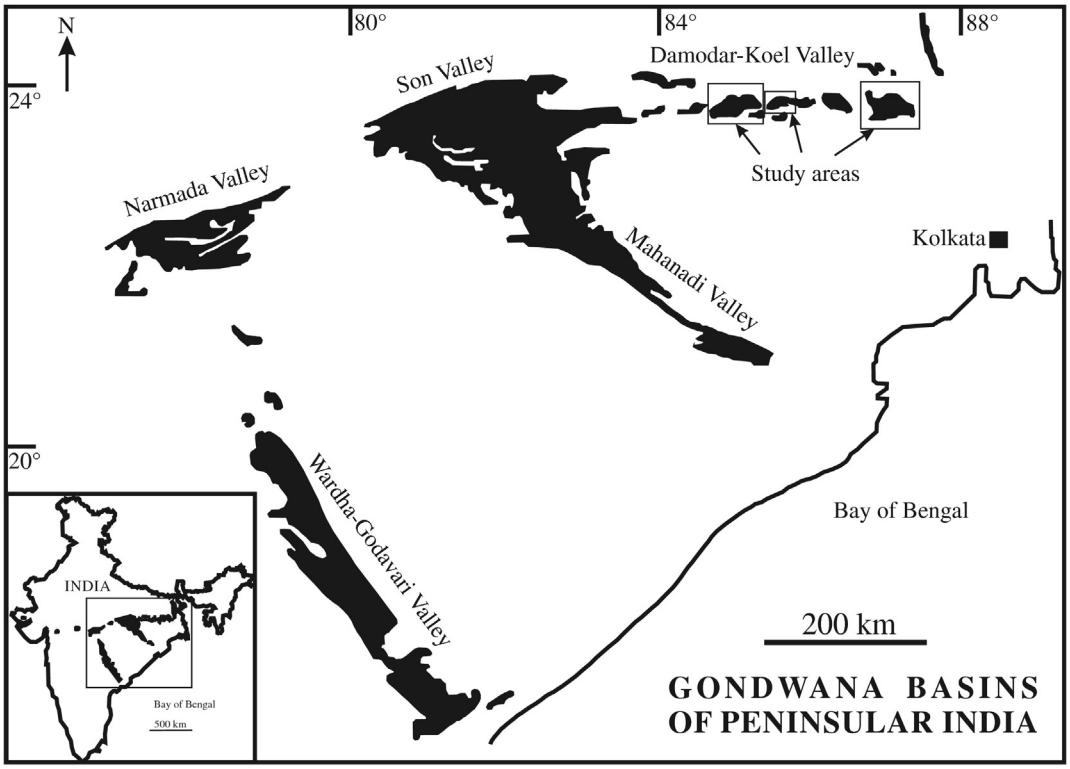

Fig. 1. Distribution of different Gondwana Basins in Peninsular India (after Srivastava and Agnihotri, 2013).