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Acritarchs - Palynomorphs from the Barren Measures Formation of West Bokaro Coalfield: Implications to Depositional Environment

Yashoda Nand Jha and H.N. Sinha*

Department of Geology, Vinoba Bhave University, Hazaribag-825301(JH), India
*(*Corresponding author, E-mail: hnsinha2003@gmail.com)*

Abstract

The Barren Measures Formation of West Bokaro Coalfield has been examined for palynological study. The present study of shale from the exposed Barren Measures Formation along the Chotha Nala section has yielded pollen, spore, AOM, phytoclast (equidimnsional and lath shaped) and acritarchs. The yield of spore, pollen, along with acritarchs and records of primary sedimentary structures attribute to a marine incursion to a fluvial setting of Barren Measure Formation. Based on the frequency distribution of acritarchs and associated palynomorphs, three zones have been proposed in which the zone II is characterised by marine incursion of high intensity as compared to zone I and II.

Keywords: Acritarchs, Spore, Pollen, Phytoclast, West Bokaro Coalfield, Marine Incursion

Introduction

The Gondwana Supergroup (Upper Carboniferous to Lower Cretaceous) distributed in the isolated depressions in the peninsular India is well known for its storehouse of the major portion of the coal reserve of the country. The Damodar Basin is one of the important basin of all Gondwana basins which hosts the sediments of Lower Gondwana succession (Upper Carboniferous to Upper Triassic) (Raja Rao, 1987) and important coal bearing lithounits like Barakar Formation (early Permian) and Raniganj Formation (late Permian). Palynofacies constituents like amorphous organic matter and opaque phytoclasts (equidimensional and lath shaped) reflect the fine-scale environmental changes and thus they have been used along with palynomorph studies to know the palaeoenvironmental reconstruction and to enhance our understanding of process driven changes in depositional settings.

It was believed that the sediments of Lower Gondwana succession were derived from glacial to glacio-fluvial, fluvial and lacustrine environment (Raja Rao, 1987; Casshyap and Tewari, 1988; Bandyopadhyay, 1996). However, the evidences of marine influence in the Lower Gondwana rocks have been observed in many places. Marine organisms *Eurydesma, Productus, Conularia* were first reported from the Umaria Marine Bed (Sinor, 1923) and subsequently from the Gondwana Supergroup of Manendragarh (Ghosh, 1954), Subansiri (Sahni and Dutta, 1959), Badhaura in western Rajasthan (Mishra *et al.*, 1961; Shah, 1963) and Daltonganj (Dutt, 1965). Evidences of marine environment were again supported with the occurrence of ichnofossils, wave ripples and tidal structures in Barakar and Barren Measures formations of different basins (Seilacher, 1964; Sengupta *et al.*, 1996). Marine palynomorphs *Leiosphaeridia (*acritarchs) is reported from the Gondwana basins of peninsular India (Tiwari *et al.*, 1995; Tripathi, 1997).

In the present work, the Barren Measures Formation has been taken into account to understand the palaeoenviromental settings of West Bokaro Coalfield (Fig.1). This coalfield is an important basin of Damoder valley. The available literature focused on the plant derived palynomorphs (spores and pollen) restricted to the biostartigraphic significance in this basin (Anand-Prakash *et al*., 1979; Murthy, 2017). The palaeoenviromental aspect is not available in detail for this formation. Barren Measures Formation is a non-coal lithounit lying between Baraker and Raniganj formations. The palynological investigation is carried out from this formation for understanding the palaeoenviroment. The yielded palynomorphs are acritarchs, spores, pollen, AOM *etc.* from this Formation (Fig. 2-4).

The recovered acritarchs is chiefly *Michrysteridium breve*, *Micrhystridium karamurzae*, *Actinotodissus* sp. The Permian acritarchs is very small in size; usually it does not reach the diameter of 20 μm (Lei *et al.*, 2019). The species *Micrhystridium breve* and *Micrhystridium karamurzae* reported from Permian sections of the Salt Range of West Pakistan, Canada and Australia (Sarjeant, 1970; Utting, 1978; McMinn, 1982). Presence of *Micrhystridium* sp. in Permian palynoassemblage represent marine environment. The yielded pollens are bisaccates *eg. Verticipollenites oblangus, Rhizomaspora indica* and *Praecolpatites sinuosus* which are of terrestrial origin. On the basis of detail palynological, and sedimentary structures (Fig.3) a depositional model has been prepared (Fig.5) and a boundary between marine and non marine

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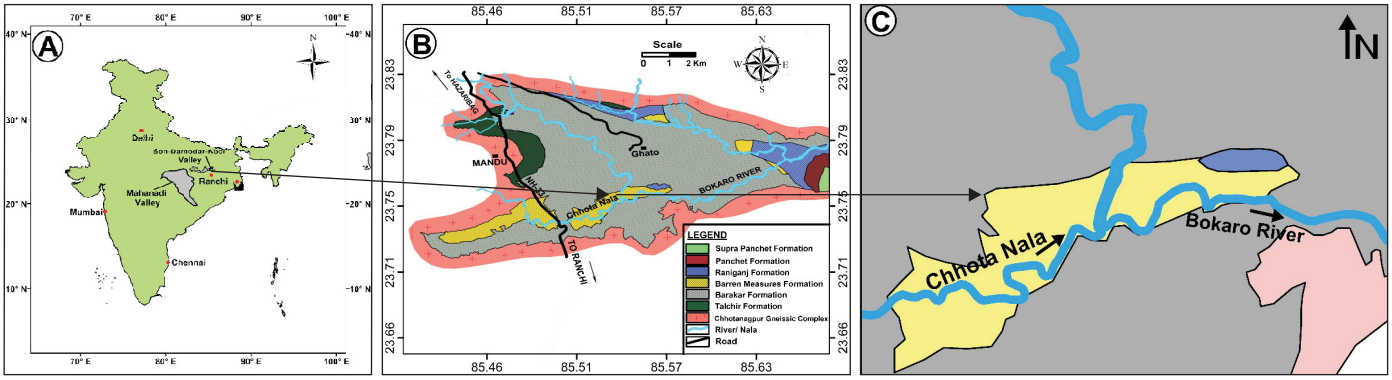

Fig. 1. (A) Location and distribution of the Gondwana valley basins of Peninsular India (B) Geological map of the West Bokaro Coalfield, India (*After* Bhattacharya and Banerjee, 2015). (C) Detail geological map of the study section in basin.

sedimentation has been marked to understand the fine changes in the palaeoenvironmental (fluvial to shallow marine) settings in the basin.

The spores, pollen along with acritarchs recovered from Lower Gondwana Supergroup represent the global temporary explosive spread of stress-tolerant acritarchs and the most survived ones possibly from the Tethyan marine transgression (Lei *et al.*, 2013b; Jha and Sinha, 2021) This transgression justify the global transgression of Permian and the possible marine incursion in the basin may have occurred from the eastern continental margin along western Australia through a passage between the Indian southern margin and the western margin of Antarctica (Gradstein *et al.*, 2004; Jha *et al.*, 2020).

Geological Framework

Majority of Gondwana sediments belonging to Permian and Triassic sequences occur within the suture zone of Precambrian blocks along linear belts, namely Damodar, Son, Mahanadi, Satpura and Godavari basins (Vaidyanadhan and Ramakrishnan, 2010). These basins are characterized by boundary faults having graben and half-graben geometry (Mukhopadhyay *et al.*, 2010). The Damodar basin lies in E-W trending narrow linear belt of isolated depressions and comprises of an excellent sequence of about 3000m thick Lower Gondwana sediments ranging in age from Permo-Carboniferous to the Upper Triassic.

The West Bokaro Coalfield is a part of Damodar Basin and consists of about 1500 m thick, well preserved Lower Gondwana succession which lie unconformably above the Precambrian basement of granitoids and amphibolites (Fig.1). The sediments in the West Bokaro Coalfield are mainly represented by glaciomarineTalchir Formation of late Carboniferous-early Permian and is characterized by rocks like tillite, conglomerate, coarse to medium sandstone and laminated shale including varves, rythmites and dropstones.

Karharbari Formation of Early Permian age overlying the Talchir Formation is only exposed in western part of coalfield and composed of coarse to very coarse grained sandstone, carbonaceous shale having thin coal seams. Barakar Formation belonging to Early Permian age lies over the Karhabari Formation and is characterized by thick pile coarse grained sandstone, carbonaceous shale, fire clays and economic coal seams.

The study section of the Barren Measures Formation is exposed mainly along the northern boundary of the West Bokaro Coalfield along the river Chotha Nala, Bokaro River, and Chutua Nala (Bhattacharya and Banerjee, 2015). Barren Measures Formation lies over the trough cross-stratified sandstone of Barakar Formation and is characterized by thick sequence of grey micaceous shale and carbonaceous shale alternating with cross-bedded fine to medium grained, compact ferruginous and siliceous sandstones. Sandstones comprise of sedimentary structures like wave ripples, trough crosses stratification, tidalites, flaser bedding having mud drapes (Fig. 3 I-K). Bioturbation is common within sand beds.

The Raniganj Formation lying over the Barren Measures is exposed in the Chotha Nala comprising of chiefly lenticular sandstones and carbonaceous shale with thin calcareous band in carbonaceous shales.

Materials and Methods

The palynological study has been carried out from the exposed Barren Measures Formation of 130m along the Chotha Nala section. Eleven samples of fresh grey micaceous shale and carbonaceous shale from bottom to top were collected. The sample position has been shown in figure 2. Samples were collected from an outcrop section of the lower middle part of the Barren Measures Formation. During sample collection, lithology and the sedimentary structures like wave generated ripples, trough cross bedding and bioturbation were taken into account.

Fifty gram of crushed shale rock in the size range of 2 to 4 mm from each sample were first treated with 32% Hydrochloric acid (HCL) to remove any carbonate material. The residues were treated with 48% hydrofluoric acid (HF) to remove silicate minerals and were finally treated in nitric acid (HNO_3). The residue of decomposed material was washed four times with distilled water by centrifuging. The resulting residue was then treated with heavy liquid using KI_2, CdI_2 and ZnI_2 to concentrate and separate the organic float from the inorganic residue. The yielded inorganic residue settles at the base of the test tube. This organic residue was washed and sieved, and then four slides were prepared from each fraction. The organic matter has been classified into phytoclasts, palynomorphs (spores, pollens, and acritarchs) and Amorphous Organic Matter (AOMs) based on the work of Tyson (1995). Relative percentage of the above mentioned components are presented on the counting of more than 100 forms for each sample. The slides were examined and microphotographed under light microscope (Leica DM-2500) and stored in the Department of Geology, Vinoba Bhave University (VBU), Hazaribag.

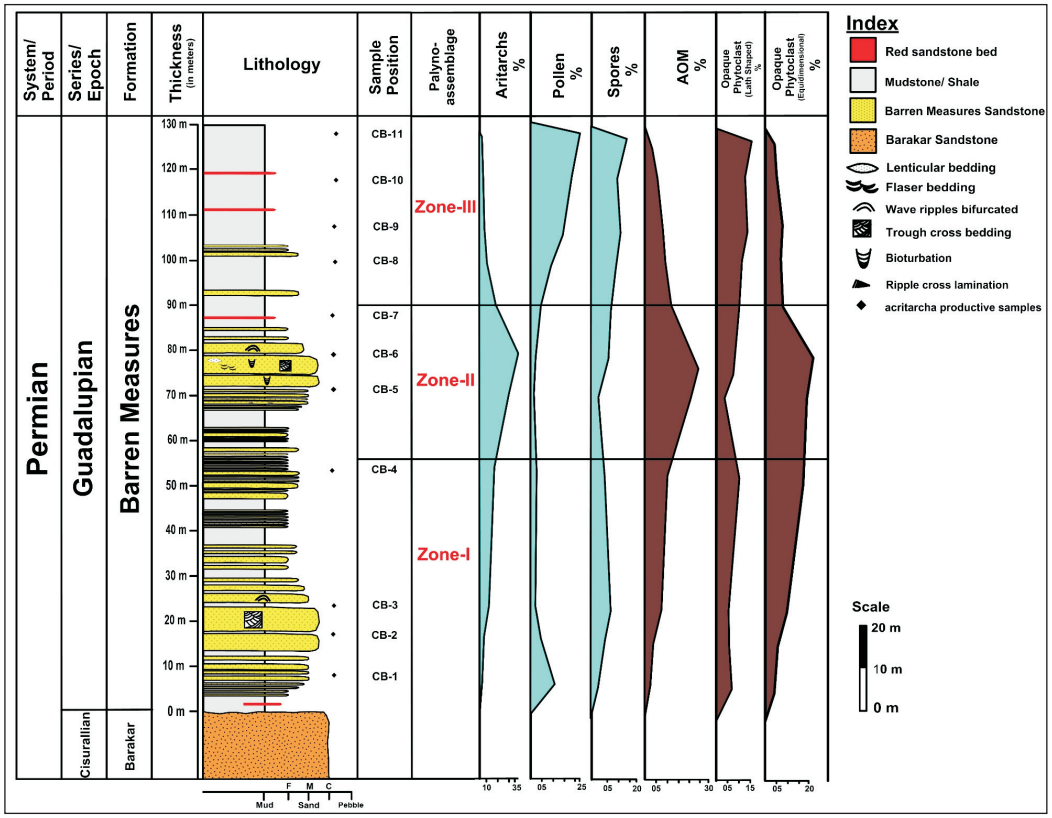

Fig. 2. Schematic lithosratigraphic log and vertical percentage frequency distribution of the palynomorphs and other organic particles from Barren Measures Formation of the west Bokaro Coalfield.

Results and Discussion

The Barren Measures Formation attain a maximum exposed thickness of 130m along the Chotha Nala section in which 11 shale samples have been collected (Fig. 2). All the samples (CB-1 to CB-11) have yielded various palynomorphs such as pollen, spores, acritarchs, AOM, OP (lath shaped) and OP (equidimensional). Their qualitative and quantitative vertical distribution in percentage has been shown (Fig. 2). Acritarchs are known as indeterminable organic walled palynomorph with unknown biological affinities (Evitt, 1963; Servais, 1996) and palaeoenvironmental indicator of deltoid region, brackish regime and closed water bodies with high salinity (Traverse, 1988). In the present work the vertical distribution of acritarchs has been considered for the creation of three distinct zones based on the low (1-10%) to high (11-35%) percentage value of acritarchs due to its occurrence in marine palaeoenviroment and representing stress-tolerent phytoplankton (Lei *et al*., 2013b). Hence, sample CB-1 to CB-4 is identified as Zone I; CB-5 to CB-7 as zone II; and CB-8 to CB-11 as zone III (Fig.2). All these assemblages also includes pollen, spore, AOM, OP (lath shaped) and OP (equidimensional) (Fig. 2-4). Acritarchs represent stress-tolerant phytoplankton (Lei *et al.*, 2013b), and can be used as excellent tool for paleoenviromental tool for sedimentation and depositional process in basin. Study carried on Permian acritarchs are very limited, literature reveals that the most of Permian acritarchs have low diversity and low concentration and it indicates a shallow marine environments or lagoon environment (Stricanne *et al.*, 2004; Lei *et al.*, 2012, 2013a) *e.g.* presence of high numbers of the taxa *Baltisphaeridium*, *Micrhystridium* and *Veryhachium* suggest marine environment (Li *et al.*, 2004).

In the current work, middle Permian (Gaudalupian) section is dominated by acritarchs taxa *Micrhystridium* sp. which shows diverse forms and is helpful to interpret the palaeoenvironment. *Micrhystridium* ranges from the Neoproterozoic to Cenozoic (Fensome *et al.*, 1990), but was particularly diverse and abundant during the Palaeozoic (Downie, 1967).

Zone I

This zone ranges from 0 to 58m (Fig. 2) with dominant lithology of shale and sandstone (CB-1 to CB-4) and is characterized by the following: occurrence of acritarchs is low in number which varies from (0.92 to 9.26%) along with pollen (2.23-13.06%), spore (0-9.23%), AOM (1.83-12.86%), OP lath shaped (8.19-9.36%) and OP equidimensional (4.12-16.48%). The important sedimentary structure of this zone is large trough cross strata in sandstone exposed at certain intervals within the succession (Fig. 3). The dominant pollen grain is *Verticipollenites oblangus* (Fig. 3H). The *acritarchs* are mainly *Micrhystridium sp.* The presence of abundant lath–shaped phytoclast along with sandstone reflects deposition along active fluvial channels under relatively high energy oxic environment (Williams, 1992; Tyson, 1995; Wheeler and Götz, 2017). However, the association of acritarchs in little amount reflects marine incursion in dominant fluvial condition.

Zone II

This zone ranges from 58m to 90m (CB-5 to CB-7) and characterized by shale, sandstone and occasional red sandstone

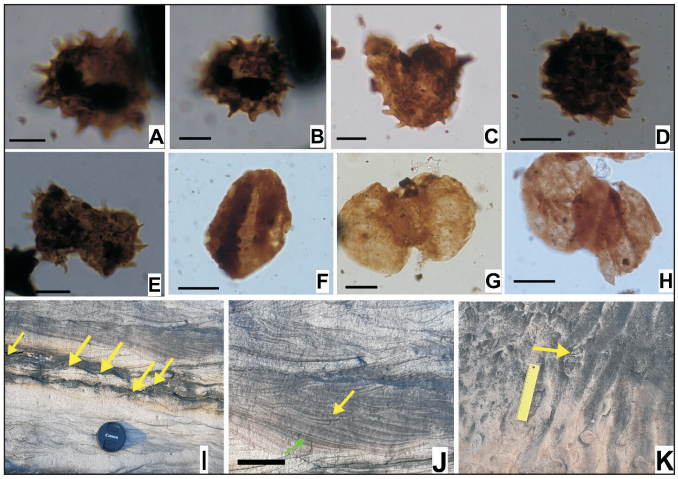

Fig. 3. (Bar =10µm), Palynomorphs from the Barren Measures Formation of the West Bokaro Coalfield: A-B. *Micrhystridium breve* Jansonius, 1962: A. Slide No. CB-6(3), coord.107x70.6; B. Slide No. CB-6(3), coord. 107x71; C. *Micrhystridium karamurzae* Sarjeant, 1970 Slide No. CB-2, coord112x32; D. *Micrhystridium* sp. Slide No.CB-10, coord.110x32; E. *Actinotodissus* sp. Loeblich and Tappan, 1978, Slide No. CB-5(2), coord. 95x27; F. *Praecolpatites sinuosus* Balme and Hennelly, 1956; Bharadwaj and Srivastava, 1969, Slide No. CB-7(1), Coord. 96 x70; G. *Rhizomaspora indica* Tiwari, 1965, Slide No. CB-7(1), coord.105x53; H. *Verticipollenites oblangus* Bharadwaj, 1962, Slide No. CB-9(1), coord.112x24, Field photographs of the sandstone bed; I. Wave ripples (arrow marked) with wavy-bedded sandstone–mudstone rock, diameter of lens cap is 52 mm.; J. Trough cross-strata with tidal bundles and reactivation surfaces (arrow marked yellow) within cross-stratified beds of sandstone, scale = 10cm.; K. Exposed bedding surface of sandstone beds showing symmetrical wave ripples having bifurcation of the crests is common (marked by arrow), scale length is 10cm.

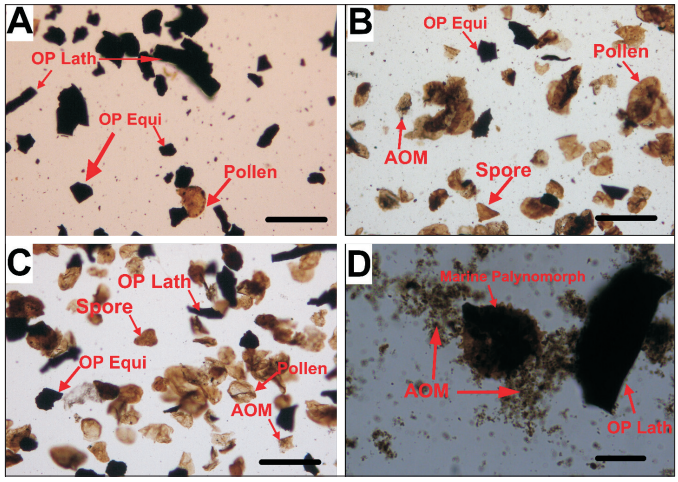

Fig. 4. (Bar=100 µm) Photomicrographs representing the recorded palynoassemblage from study section: A. palynoassemblage showing OP = opaque phytoclast, OP Equi= opaque phytoclast equidimensional, OP lath= opaque phytoclast lath shaped and pollen grains marked by arrow. B. palynoassemblage showing AOM= Amorphous organic matter, OP Equi = opaque phytoclast equidimensional, and trilet spore marked by arrow. C. palynoassemblage showing trilet spore at centre, AOM= Amorphous organic matter, OP lath= opaque phytoclast lath shaped, OPEqui = opaque phytoclast equidimensional and pollen grain. D. palynoassemblage showing large opaque phytoclast lath shaped, AOM= Amorphous organic matter, and a marine palynomorph.

beds (Fig. 2). Bioturbation is frequently observed in sandstone along with lenticular bedding, flaser bedding, mud drapes, bifurcated wave ripples, and trough cross bedding (Fig. 3). The wave ripples are smaller height with straight to sinuous crests (Fig. 3K) which reveal a shallow water depth above the wave base. The mud drapes (Fig. 3J) suggests the change in initial unidirectional current to oscillatory current flow (Myrow and Southard, 1991; Yang *et al.*, 2008; Fan, 2013). The palynomorphs of this zone includes high yield of acritarchs (13.88 to 32.40 %), AOM (11.03 to 22.05%), comparatively poor in spore (3.07 to 10.77%), pollen (1.49to 3.73%) and lath shaped opaque phytoclasts (3.51 to 8.43%). However, equidimensional opaque phytoclast (7.14 to 19.23%) are moderate in concentration (Fig.2). *Verticipollenites oblangus* still continue with less number in this zone. Acritarchs are dominated by *Micrhystridium* sp., attributes to maximum flooding (Wall, 1965; Vecoli, 2000) and reveals a near shore marine setting (Lei *et al.*, 2019). Presence of spore, pollen and others along with acritarchs and primary sedimentary structures reveals a major transgressive event took place during the deposition of this zone with over all shallow marine palaeoenviroment in a fluvial domain (Fig.5).

Zone III

This zone ranges from 90m to 130m (CB-8 to CB-11) and characterized by medium to fine grained sandstone, shale and intermittent layers of red sandstone (Fig. 2). This zone is again characterised by low concentration of acritarchs (1.85 to 5.55%) and AOM (1.83 to 5.51%) along with moderate concentration of spore (12.30 to 15.38%), pollen (11.19 to 22.38%) and OP lath shaped (9.3 to 14.05%). The equidimensional phytoclast are low in concentration (1.37% to 5.49%). Pollens are identified as *Praecolpatites sinuosus, Rhizomaspora indica* and *Verticipollenites oblangus* (Fig. 3F-H). Acritarchs are *Micrhystridium* sp. and *Actinotodissus* sp. (Fig. 3D-E). The red sandstone beds are an indicative of slight warming up of climate with lesser rainfall (Vijaya, 1995). Presence of AOM attributes to an anoxic environment (Wheeler and Götz, 2017). Low concentration of acritarchs along with moderate yield of spore and pollen attributes to a marine influx in a fluvial setting.

Conclusions

The qualitative and quantitative distribution of

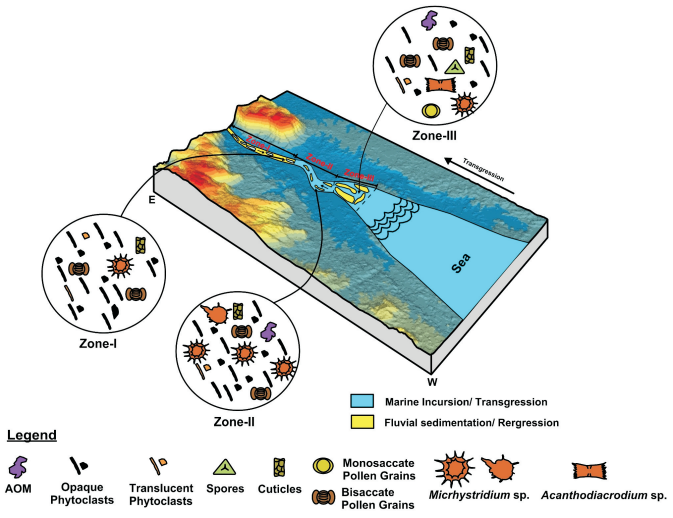

Fig. 5. Conceptual model of paleoenviroment variation in the Barren Measures Formation of the West Bokaro Coalfield, Gondwana basin of peninsular India based on palynomorph study (*After* Götz *et al.*, 2018).

palynomorphs (spore, pollen, acritarchs *etc.*) led to the creation of three zones in which zone II is characterised by a transgressive marine incursion in a fluvial domain of Barren Measure Formation. The records of primary sedimentary structures are also taken into account for the interpretation of depositional environment. The palynological findings and sedimentary structures together attribute to the marine incursion intermittently under the fluvial setting.

Authors' Contributions

Y.N. Jha: Investigation, Writing –Original Draft, Formal Analysis. **H.N. Sinha:** Supervision, Conceptualization, Reviewing and Editing.

Conflict of Interest

Authors declare no conflict of Interest.

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