Kerogen typing using palynofacies analysis in Permian Barren Measures Formation in Raniganj sub-basin, East India.

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ABSTRACT

Ahmed W, Bhat GM, Mclennan J, Sinha HN, Kanungo S, Pandita SK, Singh Y, Hakhoo N, Hafiz M, Thusu B & Choudhary NH 2018. Kerogen typing using palynofacies analysis in Permian Barren Measures Formation in Raniganj sub–basin, East India. The Palaeobotanist 67(2): 113–122.

The objective of the study is the simple assessment of kerogen type in Barren Measures Formation shale using palynofacies. The Barren Measures Formation sandwiched between the coal–rich formations consist of organic–rich black carbonaceous shales. These ~1000 m thick, black shales are in the productive gas window having kerogen types III with excellent gas generation potential as proven in recent pyrolysis studies. In this study, the palynological analysis of the four core samples of the Barren Measures Formation shale was done. The analysis has revealed three types of kerogen assemblages, viz. palynomorphs, phytoclasts and amorphous organic matter. The palynomorph assemblage consists of spores and pollen; phytoclasts consist of secondary xylem wood macrophyte plant debris and amorphous organic matter is a higher plant decomposed product. Based on the application of published kerogen classification and correlation of Tyson (1995), the pure kerogen type in these shales is categorized as mixed type; type II (oil prone) and type III (gas prone). However, the gas–prone kerogen assemblage gets relatively dominant in the samples from greater depth in the studied borehole. Our results are analogous to the previously published outcomes of kerogen typing evaluated using Rock–Eval pyrolysis experiments.

Key–words—Kerogen, Palynofacies, Thermal maturity, Barren Measures Formation, Damodar Basin.

पूर्वी भारत की रानीगंज उप–द्रोणी के पर्मियन बंजर संस्तर शैलसमूह में परागाणु संलक्षणियां विश्लेषण प्रयुक्त करते हुए केरोजैन टाइपिंग

वक़ार अहमद, जी.एम. भट्ट, जे मैकलेन्नन, एच.एन. सिन्हा, एस. कानूनगों, एस.के. पंडिता, वाई. सिंह, एन. हखू, एम. हाफ़िज़, बी. तुसु एवं एन.एच. चौधरी

सारांश

परागाणु संलक्षणियां प्रयुक्त करते हुए बंजर संस्तर शैलसमूह शेल में केरोजैन टाइप का साधारण मूल्यांकन इस अध्ययन का उद्देश्य है। कार्बनिक–प्रचुर काली कार्बनमय शेलों से सन्निहित बंजर संस्तर शैलसमूह कोयला–प्रचुर शैलसमूह के मध्य अंतर्दाबित हो गया। ये ~1000 मी. स्थूल, काली शेलें जैसा कि हाल ही के तापांशन अध्ययनों में सिद्ध हुआ है। उत्कृष्ट गैस जनन संभाव्य सहित केरोजैन टाइप III युक्त उत्पादी

गैस गवाक्ष में हैं। इस अध्ययन में, बंजर संस्तर शैलसमूह शेल के चार क्रोड नमूनों का परागाणविक विश्लेषण किया गया। विश्लेषण से केरोजैन समुच्चयों के तीन प्रकारों अर्थात परागाणुसंरूप, पादप खंडज और अक्रिस्टलीय कार्बनिक पदार्थ का पता चला है। परागाणुसंरूप समुच्चय बीजाणु एवं पराग सन्निहित; पादप खंडज द्वितियक जायलम काष्ठ स्थूलपादप मलबा सन्निहित तथा अक्रिस्टलीय कार्बनिक पदार्थ उच्चतर पादप अपघटित उत्पादक है। प्रकाशित केरोजैन वर्गीकरण के अनुप्रयोग एवं टायसन (1993) के सहसंबंध के आधार पर, इन शेलों में शुद्ध केरोजैन टाइप मिश्रित टाइप; टाइप II (तेल प्रवृत्त) और टाइप III (गैस प्रवृत्त) के रूप में वर्गीकृत है। फिर भी, गैस प्रवृत्त केरोजैन समुच्चय अध्ययन किए गए वेध–छिद्र में ज़्यादा गहराई से प्राप्त नमूनों में सापेक्षतया प्रबल रहती है। हमारे निष्कर्ष रॉक–इवल तापांशन अनुप्रयोगों को प्रयुक्त करते हुए केरोजैन टाइप मूल्यांकित किए गए के पूर्व में प्रकाशित हुए के सदृश हैं।

सूचक शब्द—केरोजैन, परागाणु संलक्षणी, तापीय परिपक्वता, बंजर संस्तर शैलसमूह, दामोदर द्रोणी।

INTRODUCTION

THE Permian shales of the Barren Measures Formation lying between two major coal seams, is the potential target for the shale resources exploration in the Damodar Valley Basin. The Oil and Natural Gas Corporation (ONGC) drilled India's first exploratory shale gas well (RNSG–1) in the Raniganj sub–basin (LNG Report, 2011). The Barren

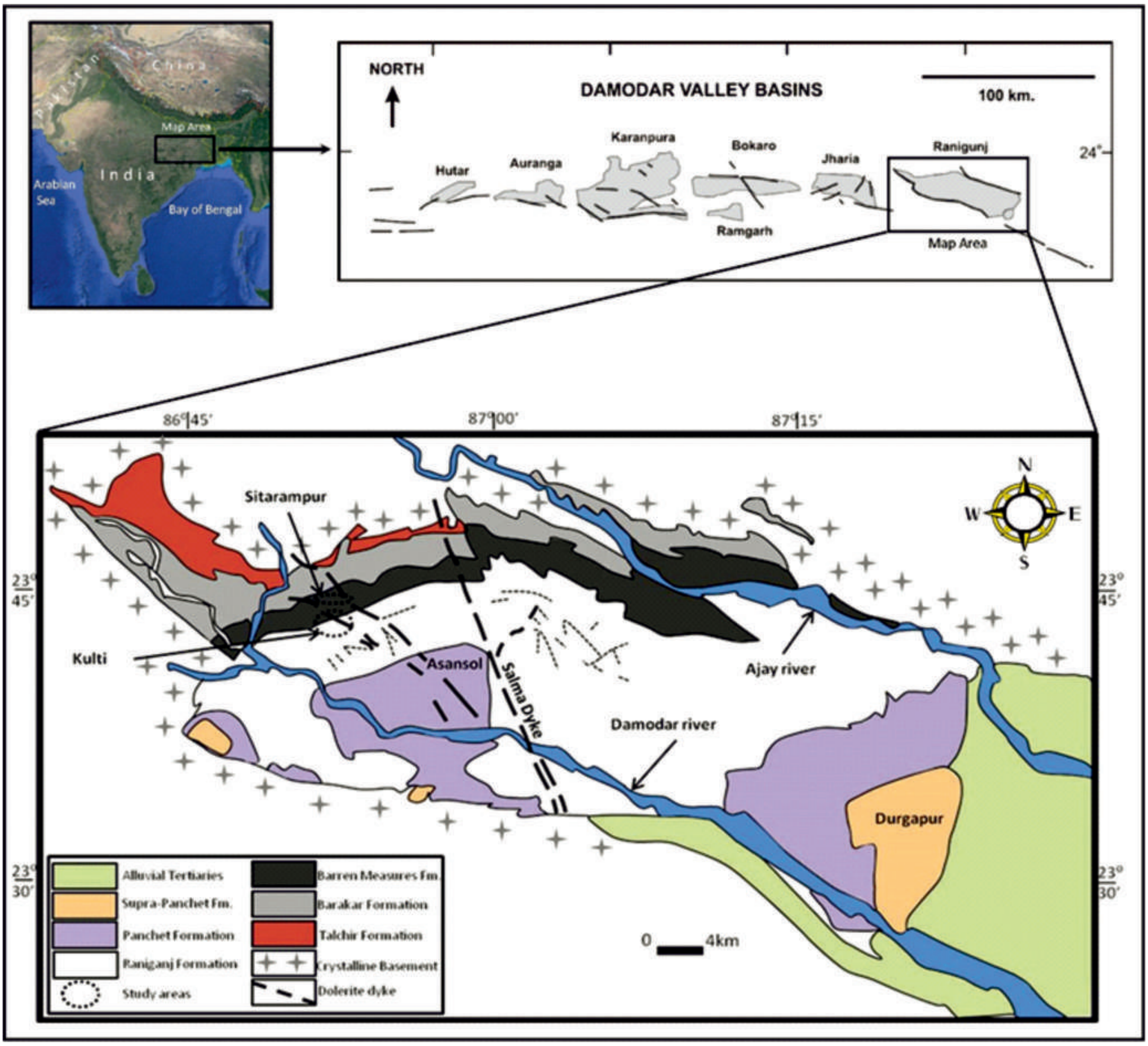

Fig. 1—Raniganj sub–basin map showing the study area (modified after Ghosh, 2002).

Measures Formation has a thick sequence of shale with high organic content and kerogen types III, with excellent gas generation potential proven by workers (Mishra, 2009; ONGC, 2010; Varma *et al.,* 2014a, b, 2015; Boruah & Ganapathi, 2015) using Rock–Eval pyrolysis techniques. This study attempts to classify kerogen type in the Barren Measures Formation shale on the base of palynofacies. There are published organic matter classifications characterized by a great deal of effort. Combaz (1964) to refer to the total organic content of a palynological assemblage (e.g. pollen, spores, micro plankton, woody tissues, cuticle, etc.) introduced the term "palynofacies". Staplin (1969) demonstrated a relationship between palynofacies (kerogen type) and genesis of hydrocarbons and was expressed in geochemical terms by Tissot and Welte (1984). The simple classifications for source rock "kerogen typing" designed for rapid assessment of hydrocarbon potential have a limited number of categories. The aim of the classification is to identify the relative proportions of inert, gas prone, oil–prone and very oil prone material within the total kerogen assemblage. The common classifications of this type are those of Correia (1971), Burgess (1974) and Bujak *et al.* (1977). The criteria given by Tyson (1995) for the selection of a kerogen classification followed in this work. The key categories of identification for a proper level of information on source rock potential are (Tyson, 1995):

1. Essentially inert material: non–fluorescent, opaque black particles generally oxidized or carbonized phytoclasts and some fungal and chitinous materials.
2. Gas–prone material: non–fluorescent, generally orange or brown, translucent, structured phytoclasts, but also translucent non–fluorescent, structure less materials. Woody fragments are typical, but partially oxidized palynomorphs and plankton derived material oil–prone material: have a similar composition.
3. Volumetrically, the most important constituent is fluorescent amorphous organic matter.
4. Highly oil–prone material: this consists of very strongly fluorescent organic matter including structured material derived from chlorococcale and prasinophyte algae and amorphous material derived from cyanobacteria and thiobacteria. Resins and some cuticles are the only significant terrestrially derived components belonging to this group.

GEOLOGY OF THE DAMODAR BASIN

The Damodar Basin is comprised of a series of sub–basins (from west to east) (Fig. 1): the Hutar, Daltonganj, Auranga, Karanpura, Ramgarh, Bokaro, Jharia and Raniganj. The present study undertaken in the easternmost, Raniganj

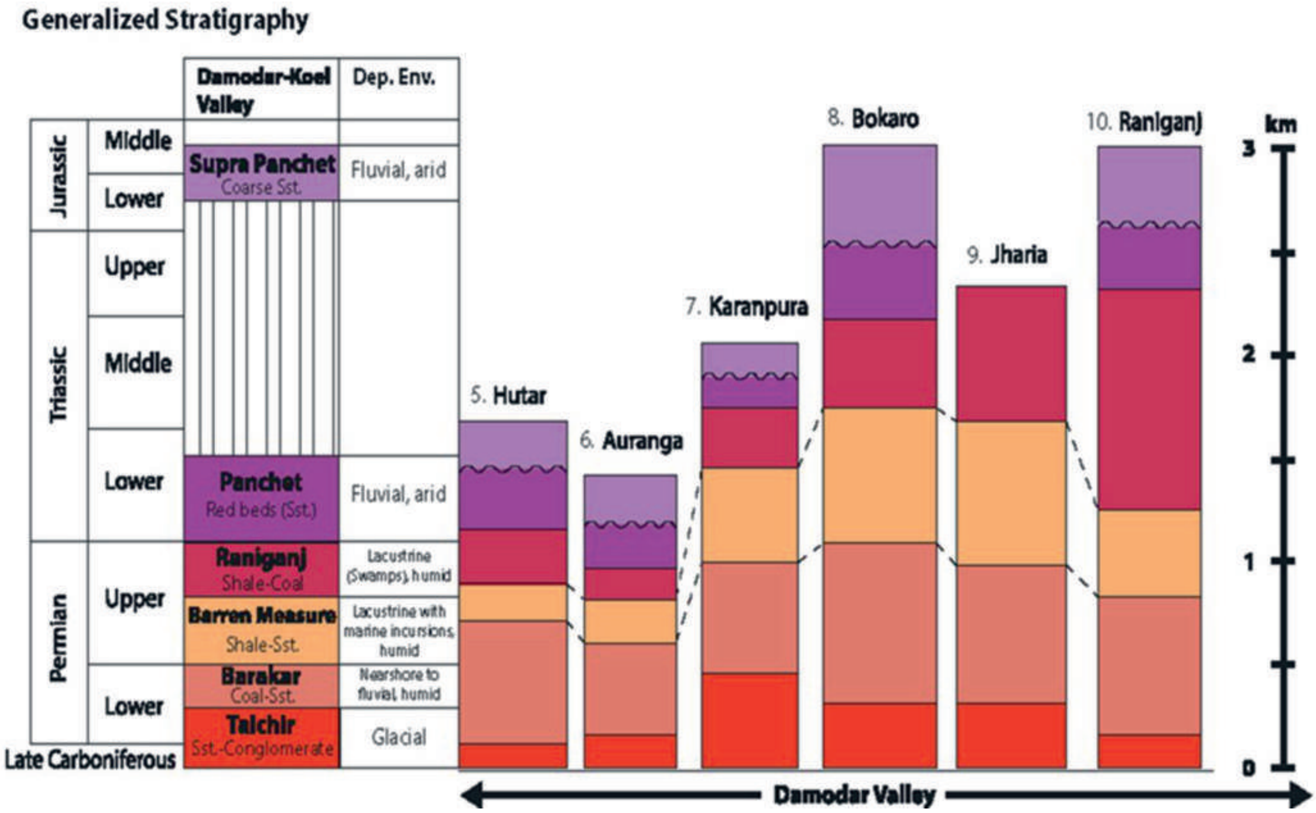

Fig. 2—The regional stratigraphic sequence in the Damodar Basin (after Mukhopadhyay *et al.*, 2010).

sub–basin; was the target of India's first shale gas exploration well. The Raniganj sub–basin is a semi–elliptical, elongated basin located between Damodar and Ajoy rivers (Ghosh, 2002). It is demarcated by latitudes 23º03' and 23º51' N, and longitudes 86º42' and 87º28' E. The sediments deposited are mainly terrestrial (fluvial and lacustrine) with local marine transgressions during the Sakmarian–Artinskian period (Ghosh, 2002; Chakraborty *et al.*, 2003). The base of the Raniganj sub–basin (Fig. 2) is comprised of the early Permian glaciogenic Talchir Formation that overlies the Pre–Cambrian metamorphic basement unconformably. The major coal seams found in the Barakar and Raniganj formations overlie the Talchir deposits. The Barakar Formation is comprised of light grey, gritty to pebbly, cross–bedded sandstone, interbedded with grey/black shale and coal, arenaceous shale (Casshyap & Tewari, 1988). The Raniganj Formation has fining upward sequences of coarse–grained to medium–grained sandstone, inter–bedded fine sandstone/shale and coal (Casshyap & Tewari, 1988). The Barren Measures Formation sandwiched between Barakar and Raniganj formations has a fluvial–lacustrine origin and is devoid of coal (Dasgupta, 2005; Murthy *et al.*, 2010). The Permian Barren Measures Formation is recognized as the prospective shale gas horizon based on thickness (>1000 m), areal extent and higher (>2%) organic matter content (ONGC, 2010; Varma *et al.*, 2014a, 2015). The overlying Panchet Formation has alluvial deposits and is also barren of coal.

METHODOLOGY

The palynofacies analysis of four samples done in this study. The samples represent Barren Measures Formation shale and belong to borehole 'ASJW/3' in Sitarampur block of the Raniganj sub–basin covering the depth range from 24 m to 391 m. Qualitative visual recognition of 'assemblage types' and semi–quantitative visual estimation of the percentage of composition was done in this work using the manual technique. The technique used for palynological slide preparation summarized in the flow chart (Fig. 3). Thin sections were prepared at the Palynology Laboratory of the Vinoba Bhave University, Hazaribagh and transmitted light microscopy using Leica done at the P.G. Department of Geology, University of Jammu, Jammu.

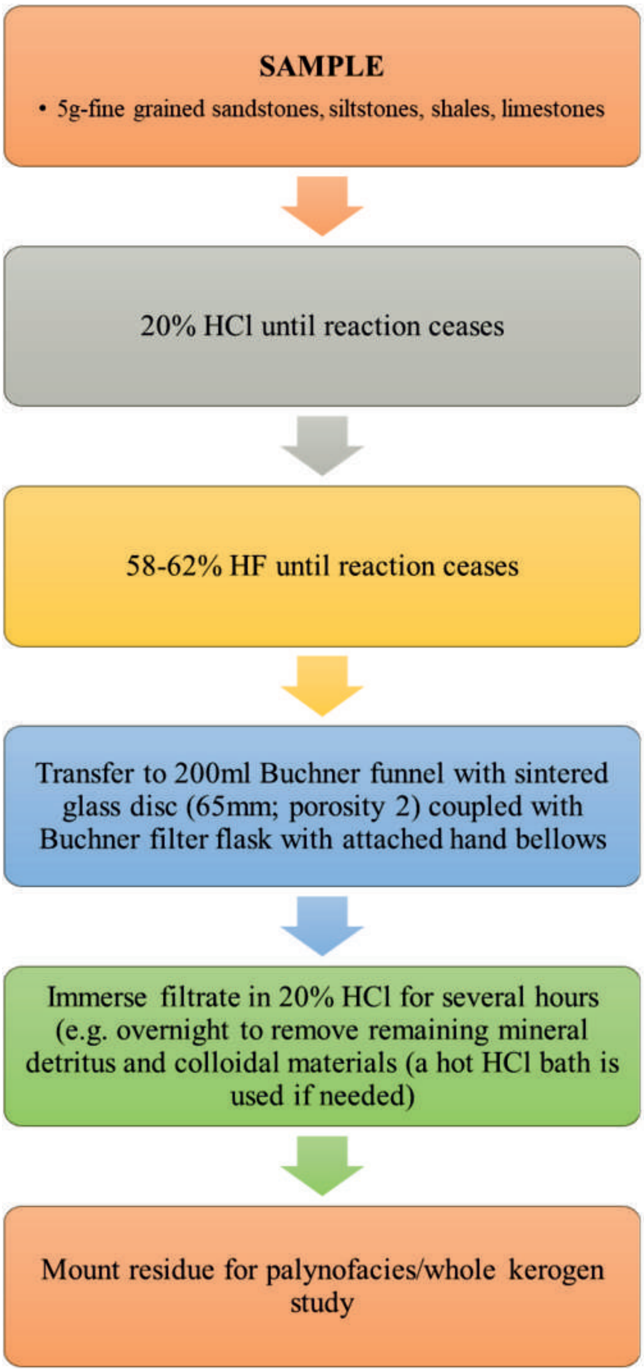

Fig. 3—Generalized flow–chart illustrating steps used for palynofacies processing (after Batten & Morrison, 1983).

RESULTS AND DISCUSSIONS

The description of each slide is as:

Sample A1 (24 m)

The slide is rich in organic matter and has a variety of palynomorphs, sporomorphs and phytoclasts. Palynomorphs include monosaccate forms as well as bisaccate forms of palynomorphs while trilete spores also noticed. The phytoclasts include translucent xylem and cortex tissues and opaque phytoclasts. The palynomorphs/sporomorphs abundance is at par with phytoclasts (Fig. 4).

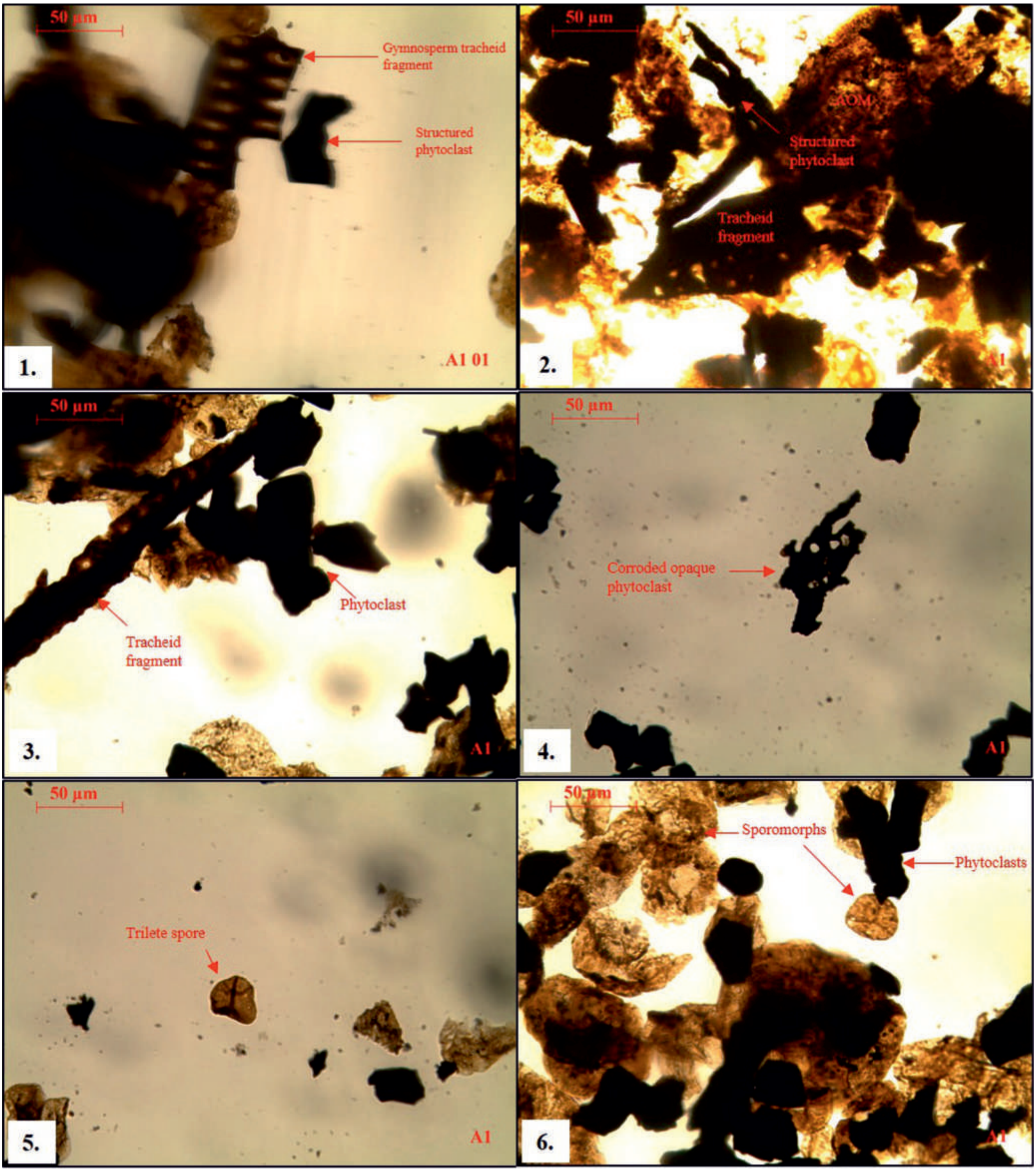

Fig. 4—Different phytoclast groups in sample A1. 1. Biostructure phytoclast composed of two gymnosperm tracheid. The longer half of the particle shows small–bordered pits in biserial–offset arrangement; structured phytoclasts, external form, and sharp distinct edges indicate structured particle but there is no visible internal biostructure. The internal structure of the particle is infilled and largely obliterated by gelification, making them massive. 2. Well preserved Amorphous Organic Matter (AOM) seen in transmitted light along with tracheid fragment and structured phytoclast. 3. Tracheid fragment having uniseriate (single row) arrangement; structured phytoclast. 4. Highly corroded opaque lath–shaped phytoclast. The internal holes in the phytoclast may be because of the dissolution of original pits. 5. A trilete spore. 6. Group of sporomorphs and phytoclasts.

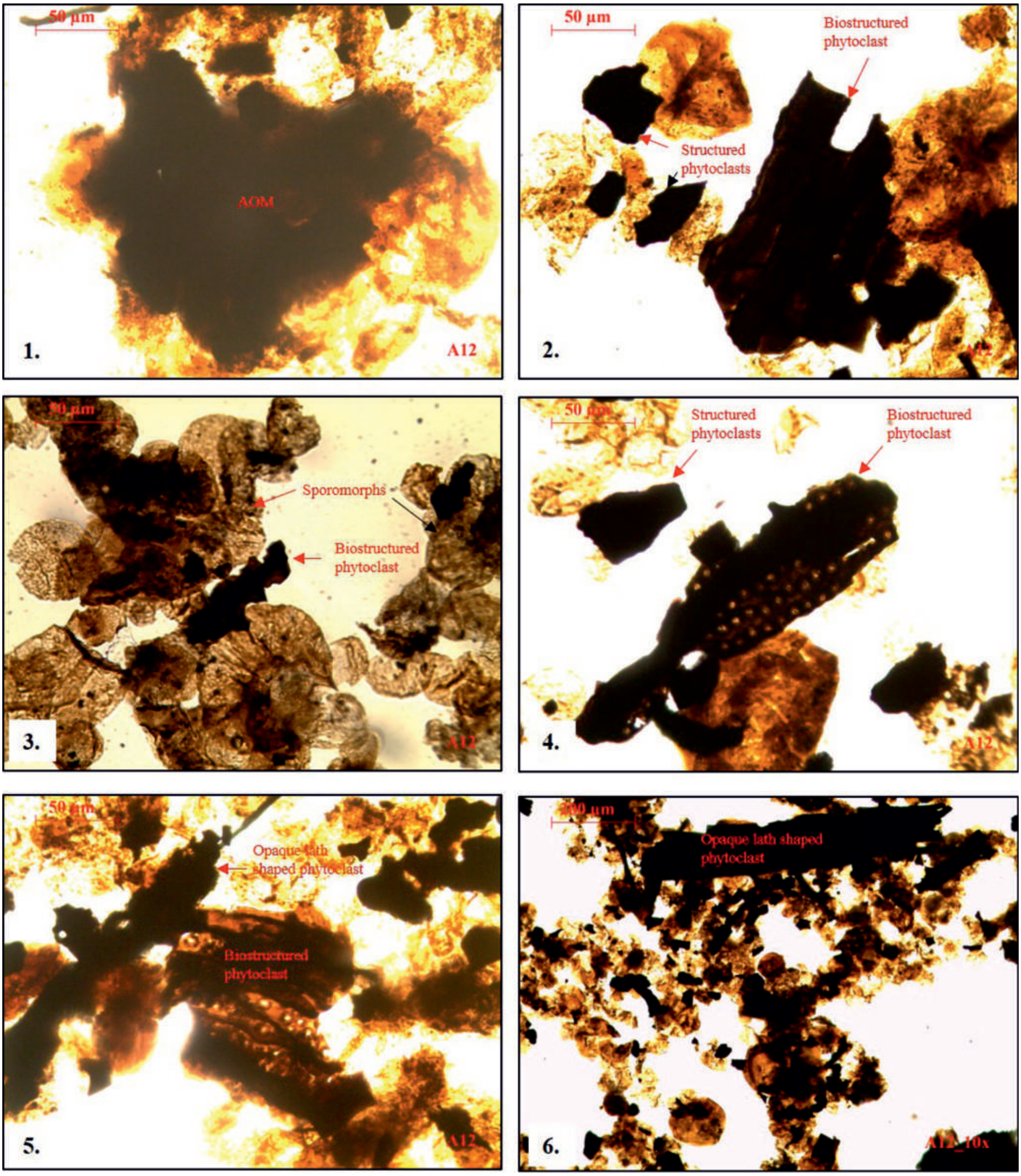

Fig. 5—Phytoclast forms in sample A12. 1. Well preserved amorphous organic matter. 2. Bio structured phytoclast undergoing disintegration along the pitted sides, and if it have had been degraded further it is probable that only the thickened strips would survive as lath shaped phytoclasts without visible biostructure. 3. Group of sporomorphs and small bio structured phytoclast. 4. Bio structured phytoclast having uniseriate arrangement of bordered pits. Structured phytoclast having distinct external form and edges. 5. Bio structured phytoclast along with opaque lath–shaped phytoclast. 6. Opaque lath–shaped phytoclast with splintery nature and good preservation of structure grain. The angular outline and the structural grain are clear evidence of structure although no definitive biostructure is present. Relatively these large laths break up into smaller opaque particles during extended transport.

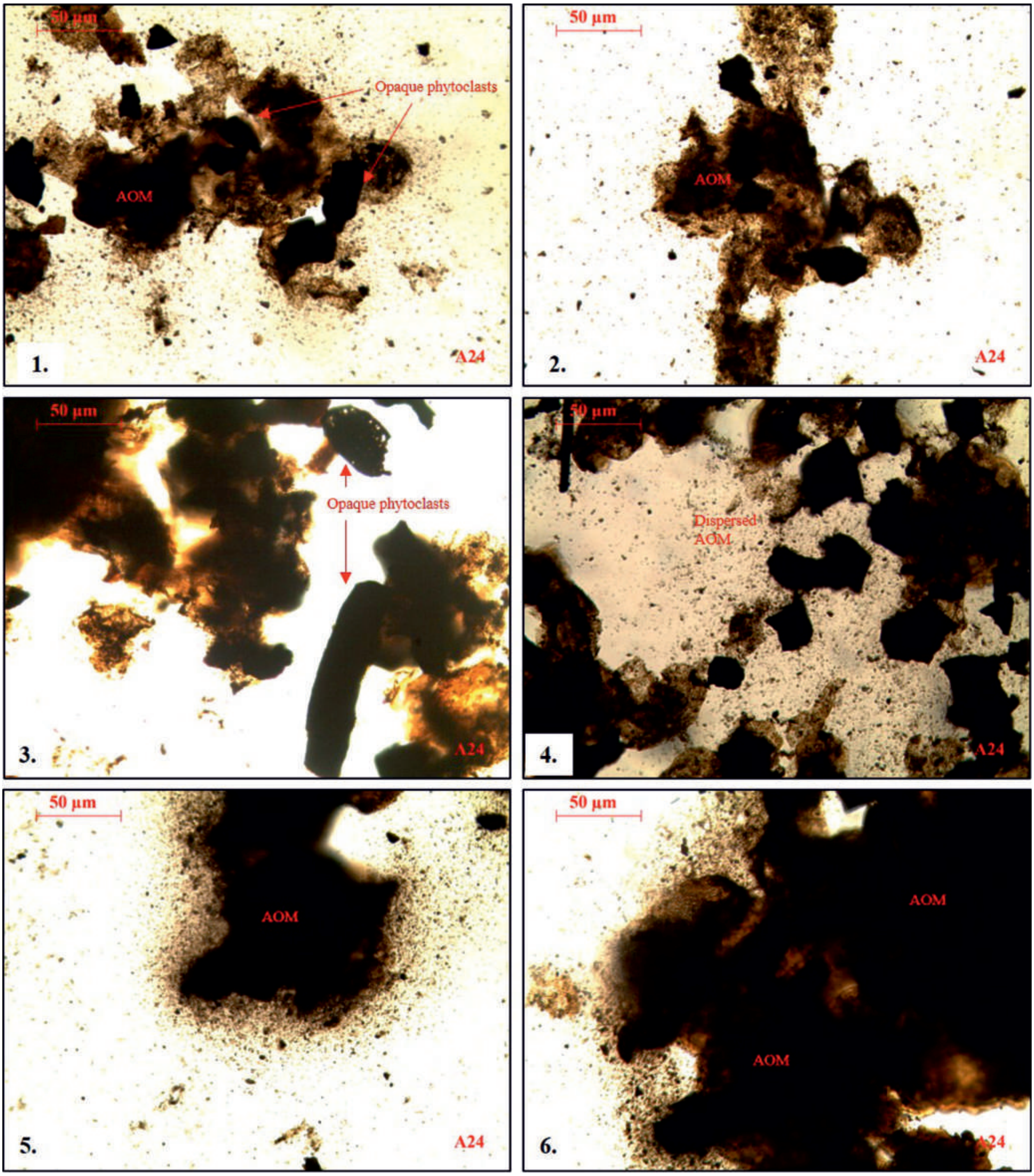

Fig. 6—Phytoclasts and amorphous organic matter types in sample A24. 1. and 2. Well–preserved amorphous organic matter (AOM) seen in the transmitted light. Note the presence of unidentifiable fragments along with inclusions of phytoclasts and palynomorphs. 3. Corroded opaque phytoclast fragments. 4. A dispersed form of amorphous organic matter along with opaque phytoclasts. 5. and 6. Well preserved amorphous organic matter.

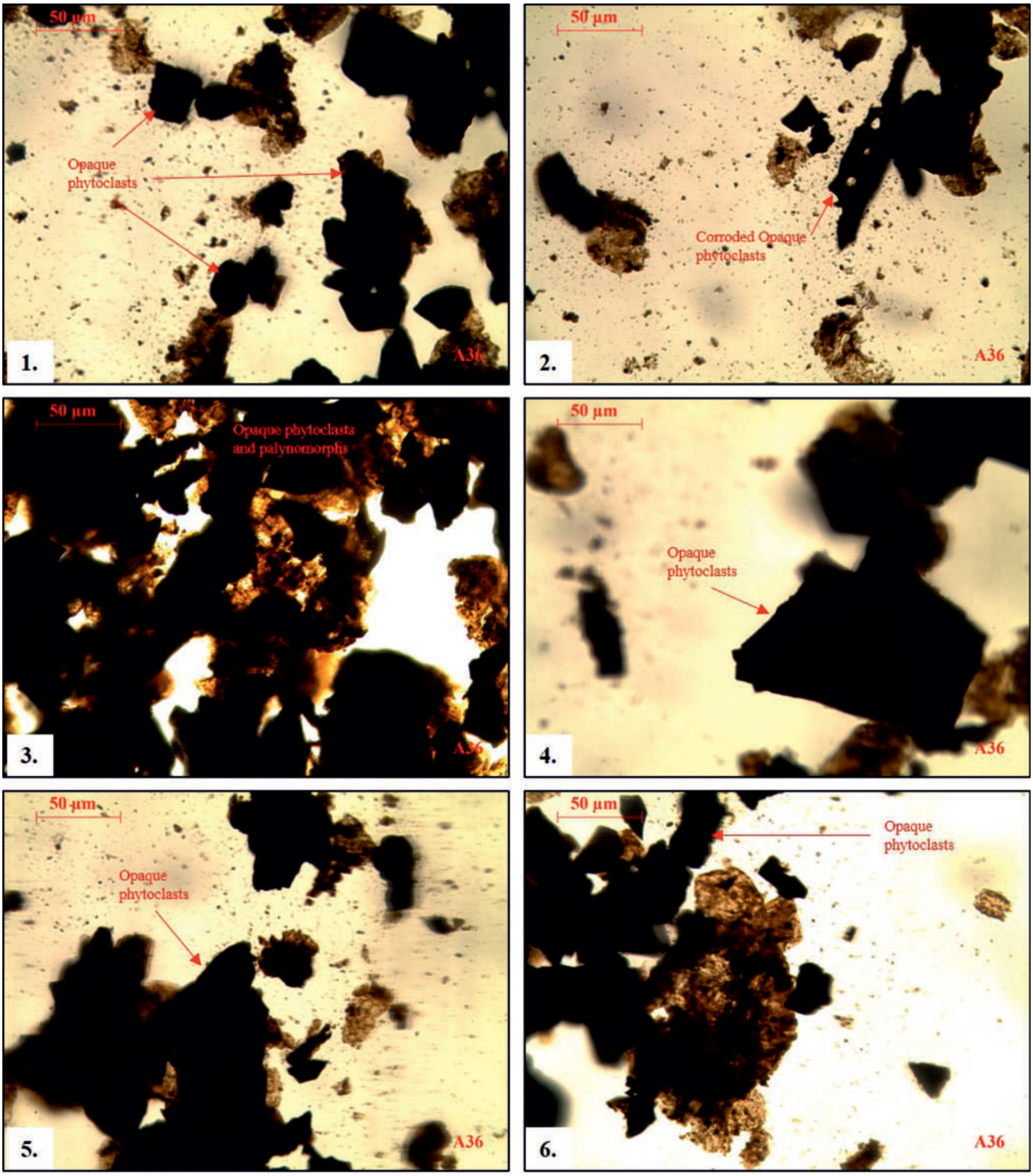

Fig. 7— Opaque phytoclasts in sample A36. Different groups of opaque lath–shaped phytoclasts as seen across the slide. Note the size of the phytoclasts as compared with the previous slides. Some have corroded shapes, and some are equidimensional while some show the presence of internal microstructural grain (structure).

Sample A12 (130 m)

The slide shows a presence of hard plant parts and cuticles along with phytoclasts. A count of hard plant parts vs palynomorphs has revealed that the hard plant parts/cuticles average 18% and palynomorphs average 22% across the slide. A dispersed form of amorphous organic matter also observed (Fig. 5).

Sample A24 (251 m)

The slide shows well preserved amorphous organic matter across the slide. A dispersed form of amorphous organic matter also seen along with opaque phytoclasts (Fig. 6).

Sample A36 (391 m)

The slide has dominance of opaque phytoclasts across the slide along with a dispersed form of amorphous organic matter. The opaque phytoclasts in this sample are more abundant than previous sample slides (Fig. 7).

Based on the results obtained, the kerogen in Permian Barren Measure Formation shale is principally composed of different forms of phytoclasts, palynomorphs and well–preserved amorphous organic matter. The observed phytoclasts group in these shales characterized by the presence of woody tissues of land plants represented by fragments of strongly lignified mechanical support and vascular tissues of the secondary xylem (wood) of gymnosperms. The other type observed is opaque and semi–opaque phytoclasts. The amorphous group is another kerogen type found in these shales which consists of all particulate organic components that appear structure less at the scale of light microscopy, including plankton–or bacterially–derived amorphous organic matter (AOM), higher plant resins, and amorphous products of the diagenesis of macrophyte tissues. The amorphous organic matter in sample A24 is a dispersed form of organic matter. Venkatachala (1984) describes a finely dispersed kerogen category associated mostly with biodegraded terrestrial organic matter and interprets it as the final stage of terrestrial material degradation. Misra (1991), observed this type of amorphous organic matter in recent outer shelf sediments of the north–west margin of India and its dominance reflects deposition removed from major phytoclast input. The third category of kerogen assemblage found in the slides is the palynomorph group further distinguished from sporomorphs, phytoplankton, and zoomorphs. Sporomorphs composed of spores, pollen and fungal spores observed in the slides. The spores observed here are composed of saccate pteridophyte spores and gymnosperm pollen and prepollen in bisaccate and monosaccate forms. Tissot and Welte argued that the relationship between microscopically identified "algal, amorphous, herbaceous, woody and coaly" organic particles and the kerogen types defined by elemental analysis is generally clear (Tissot & Welte, 1984). The likelihood of oil generation decreases across these five categories with algal and an amorphous material having the greatest potential for oil, herbaceous (spores and pollen) matter having some potential for oil and woody and coaly accumulations being essentially gas prone. As seen in the plates (figs 4, 5, 6, 7), the palynomorphs are well–preserved and dark brown to black in colour. Based upon the published 10 point Spore Colour Index (SCI) the recovered assemblages' exhibit values between 8.5 and 9 described as late mature to post mature and gas generative type (Collins, 1990; Fisher *et al.,* 1980; Sinha *et al.,* 2017). Furthermore, the assemblages recovered from the sample of deeper part of the borehole (sample A36) are darker as compared to the assemblages recovered from shallower depth sample (sample A24) signifying increasing maturity with depth. This increase in thermal maturity down the borehole may be because of the later heating of the basin basement due to igneous activity evident from the intrusions in the form of dykes and sills dated at 105–113 Ma in the Raniganj sub–basin (Ghosh, 2002).

CONCLUSIONS

The palynological analysis of the four samples from the Barren Measures Formation shale has revealed three types of kerogen assemblages, viz. palynomorphs consisting of spores and pollen; phytoclasts consisting of secondary xylem wood macrophyte plant debris and amorphous organic matter as higher plant decomposed product. Based on the published kerogen classification and correlation of Tyson (1995) the mixed type of kerogen is present in these shales; type II (oil prone) and type III (gas prone). The gas prone assemblage is relatively dominant and is thermally mature in the samples from greater depth in the studied borehole. Additionally, this study infers that the thermal maturity is increasing with depth in the Barren Measures Formation.

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