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Limitation of Petrographic Indices in Depositional Environmental Interpretation of Coal Deposits

Commentary

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Abstract: Organic petrology based petrographic indices (Tissue Preservation Index and Gelification Index) is a widely utilized tool in the study of depositional palaeoenvironment of coal. Evaluation of these petrographic indices suggests that, at present, utilize only vitrinite/huminite and inertinite macerals to interpret depositional environment of coal. Liptinite group macerals have important depositional environment implications, but liptinite macerals have not been taken into account in earlier petrographic indices (TPI and GI) formulations. This article examines the limitation of TPI and GI, and proposes improved TPI and GI indices, including the liptinite and inertinite macerals having depositional environment significance.

Keywords: petrographic indices • depositional environment • coal deposits • organic petrology • tissue preservation index • gelification index

1. Introduction

Diessel (1986) [1] introduced two petrographic indices (TPI = Tissue Preservation Index and GI = Gelification Index) and related these to prevailing swamp types (dry forest swamp, wet forest swamp, fen marsh), based on the ratio of specific maceral combinations. TPI and GI values were also used by Kalkreuth et al. (1991) [2], to define depositional environments such as upper delta plains, lower deltas, and back barriers. The gelification index is considered to reflect the height of the water table during peat accumulation, whereas tissue preservation index represents the effects of the input of woody material and its preservation prior to final deposition (Kalkreuth et al., 2000) [3].

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Diessel's (1986) [1] TPI and GI concepts were modified by Kalkreuth et al. (1991) [2] leading to the substitution of hard coal terminology by brown coal terminology.

This article presents the results of the investigation and evaluation of these petrographic indices.

2. Problem and Discussion

To interpret the depositional environment of coal precursor and petrographic indices, calculated from the diagnostic maceral compositions which are used as parameters.

On the basis of Tissue Preservation Index (**TPI**) and Gelification Index (**GI**), the ratio can be used to determine particular peat-forming environments. The ratio is formulated as follows:

GI = (Vitrinite + Macrinite) /(Semifusinite + Fusinite + Inertodetrinite)

TPI= (Vitrinite A + Semifusinite + Fusinite) / (Vitrinite B + Macrinite + Inertodetrinite).

High GI (>5) and TPI (>1) values indicate a wet condition of peat formation, whereas low GI (<5) and TPI (<1) suggest a dry condition (Diessel, 1986 and 1992) [1, 4]. Thereby, GI plays an important role in representing influence of groundwater, whereas the type of plant input is indicated by the TPI value.

Evaluation of the petrographic indices shows that the TPI and GI takes into account only the present vitrinite and inertinite macerals, and neglects the liptinite macerals present in coal. The liptinite macerals are derived from the waxy and resinous parts of plants such as spores, cuticles and resins, which are resistant to weathering and diagenesis. Liptinite group macerals have proven to be an important indicator for depositional environments in numerous studies (e.g. Parry et al., 1981 [5]; Hart, 1986 [6]; Tyson, 1987, 1995 [7, 8]). A liptinite group's maceral cuticles are most typical of a fluvio–deltaic, prodelta, estuarine–mangrove facies or proximal submarine fan facies (Tyson, 1987, 1995) [7, 8]. Cuticles have been preserved either in low energy environments, having been buried rapidly before the onset of oxidation, or in a Tertiary mangrove swamp. A dominance of spores, which forms sporinite, is considered to indicate a fresh-water input (Parry et al., 1981) [5]. Fresh-water input may develop or continuously keep wet conditions in the peatforming mires. Chlorophyllinite, which is a primary maceral within the liptinite group is derived from plant chlorophyll and is only present in peat and lignite (Teichmuller, 1989) [9]. The presence of chlorophyllinite in the lignite suggests wet and alkaline reducing conditions (Cabrera et al., 1995 [10]; Dehmer, 1995 [11]).

The Gelification index has been defined as a measure of the degree of wet conditions (Diessel, 1992) [4], as it accounts for the presence of inertinite macerals which indicate dry conditions. However, an important inertinite maceral sclerotinite (fungal remains) which is typical of oxic environment (Hart, 1986) [6], is not included in current petrographic indices. Inclusion of sclerotinite in maceral indices will help to understand the presence or absence of oxic conditions in the wet conditions of peat formation. Evaluation of published data on coal petrography very clearly points out this limitation. Petrographic data provided in Singh and Singh (2005) [12] on Panandhro lignite rank coals shows that the Panandhro lignites contain an average 80% huminite macerals, 17% liptinite macerals and 3% inertinite group macerals. In this work, utilized petrographic indices show that their depositional environment may not be completely representative as it includes inertinite macerals (3%), but excludes liptinite macerals, which is present in significant amounts. Similarly, evaluation of petrographic data on Pliocene lignite rank coals of Apofysis mine, Greece in Iordanidis and Georgakopoulos (2003) [13] shows that Pliocene lignite contains an average 81.3% huminite macerals, 6.3% inertinite macerals and 12.4% liptinite macerals. Among inertinite group, fusinite have an average 2.6%, semi-fusinite 0.4% and funginite 0.04%. In liptinite group cutinite maceral have an average amount of 3.8%, sporinite 0.9%, chlorophyllinite 0.3%. The TPI and GI based interpretation excludes liptinite macerals even though its amount is double that of inertinite macerals and have important environmental implications.

Examples of petrographic indices based environmental interpretation may not be completely representative and reliable, as it excludes liptinite group macerals and their environmental affiliations. This limitation applies to brown coal and hard coal based petrographic (TPI and GI) indices, as both indices exclude the liptinite group and their macerals.

In this study an improved modified petrographic indices (GI and TPI) are proposed. In this revised petrographic indice, cutinite, sporinite, chlorophyllinite, and sclerotinite macerals are included.

GI is a measure of the degree of wet conditions, therefeore cutinite, sporinite and chlorophyllite macerals are included in the numerator, taking into account their environmental affiliation. The sclerotinite maceral is included in the denominator, due to their oxic depositional environment, as well as inertinite group affiliation.

Modified GI = (Vitrinite + Macrinite + Cutinite + Sporinite + Chlorophyllite) / (Semifusinite + Fusinite + Inertodetrinite + Sclerotinite)

TPI is a ratio of the structured to non-structured macerals, so all primary structured liptinite macerals such as cutinite, resinite, sporinite are included in the numerator, and non-structured liptinite maceral liptodetrinite is included in the denominator.

Modified TPI = (Vitrinite A + Semifusinite + Fusinite + Sporinite + Cutinite + Resinite + Chlorophyllite + Suberinite) / (Vitrinite B + Macrinite + Inertodetrinite + Liptodetrinite)

To investigate, determine and correlate between Diessel's petrographic indices and proposed modified petrographic indices a published coal maceral data from Suwarna and Hermanto (2007) [14] was taken. Three samples (sample numbers: 2, 20 and 23) were taken and based on their maceral composition GI and TPI as well as modified GI and TPI, which were determined and then correlated with each other. Results are shown in Table 1 and Figure 1, and suggest quite significant differences between the GI and modified GI (Table 1). A comparison of both datasets suggests that the modified GI is comparatively less than the GI; whereas the modified TPI is compara-

Table 1. Maceral composition of Berau coal of Early to Middle Miocene, East Kalimantan, Indonesia (Data from Suwarna and Hermanto, 2007 [14])

S.N.	Ti	Dt	Gi	V	F	Sf	Ma	Sc	Idt	I	Re	Sp	Sb	Cu	Lpt	E/L	GI	TPI	Modified GI	Modified TPI
2	54.8	30.0	2.4	87.2	1.8	2.2	-	1.0	0.4	5.4	1.2	-	-	0.8	0.8	3.2	19.81	1.79	16.29	1.80
20	32.4	48.6	0.6	81.6	-	2.0	0.4	2.4	1.4	6.2	1.6	-	1.6	3.4	-	6.8	24.11	0.67	14.72	0.80
23	41.6	51.6	0.6	93.8	-	-	-	0.6	0.4	1.0	1.4	-	-	3.4	-	4.8	234.50	0.79	97.20	0.88

S.N. – sample number, Ti – telocollinite, Dt – detrovitrinite, Gi – gelocollinite, V – vitrinite, F – fusinite, Sf – semifusinite, Ma – macrinite, Sc – sclerotinite, Idt – inertodetrinite, I – inertinite, Re – resinite, Sp – sporinite, Sb – suberinite, Cu – cutinite, Lpt – liptodetrinite, E/L – exinite/liptinite, GI – gelification index, TPI – tissue preservation index

tively higher than the TPI (Table 1). Inclusion of liptinite macerals in modified petrographic indices decreases the GI and increases the TPI, in general (Table 1). Results shows that the Diessel model is not applicable for sample 23 (GI=234.50) due to the limit of the scale (Figure 1). Comparison between the modified GI and GI results suggest that the GI over-estimates the degree of wetness without inclusion of the liptinite group and sclerotinite maceral (Table 1). Comparison between the modified TPI and TPI results suggests that the TPI somewhat under-estimates the preservation conditions of the tissues, due to exclusion of structured and un-structured liptinite macerals (Table 1). These aspects suggest that the inclusion of liptinite group and sclerotinite macerals in modified GI and TPI is quite rational in its utility in coal facies study. These modified petrographic indices gives equal weightage to those liptinite and inertinite maceral which have significant environmental implications, and so these modified indices are more representative of overall macerals and their depositional environment present in a sample.

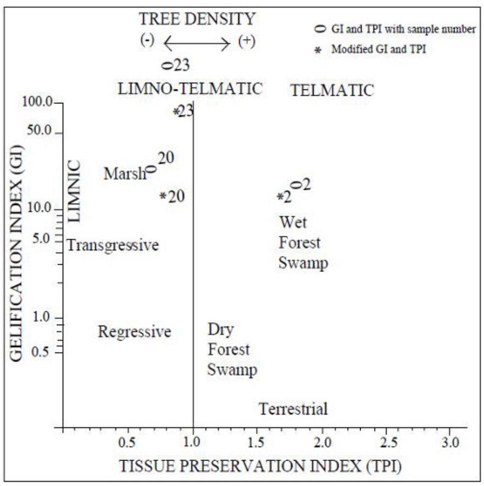

Figure 1. Coal facies diagram as developed by Diessel (1986) [1] and position of studied samples analyzed in this study.

3. Conclusion

This article points out the limitation of the petrographic indices (TPI and GI) and presents an improved TPI and GI. The improved TPI and GI take into account those liptinite and inertinite macerals which have significance from a depositional environment point of view. The utility of these improved indices will further increase the reliability in petrographic indices based depositional environment interpretations.

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