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Pliocene pollen and spores from Sajau Coal, Berau Basin, Northeast Kalimantan, Indonesia: Environmental and Climatic Implications

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Abstract: ***New data on paleovegetation and paleoclimate during the Pliocene has been obtained from palynological analysis of the Pliocene age coals of Sajau Formation in the eastern part of the Berau basin, Northeast Kalimantan, Indonesia. Most of palynomorphs are recognizable from the coal sample in well-preserved condition. Pollen and spores were dominantly derived from terrestrial, with a low proportion of dinoflagellates. The presence of fresh water pollen and a lesser dinoflagellates cysts indicated that coals were deposited under fluvio-deltaic systems. The increasing of dinoflagellates cysts should be related with the transgression event. The presence of Dacrycarpites australiensis and Monoporites annulatus), dominated with Meliaceae, Rubiaceae, Lanagiapollis sp., and Sapotaceoidaepollenites supported the late Pliocene age. During the Pliocene in Berau Basin, warm/wet climate was suggested occurred in sedimentation of coal seam- A, coal seam- K and coal seam-L which identified by dominated the arboreal pollen (AP) comparing the Non-arboreal pollen (NAP) while coal seam-B was formed under dry season (low AP, high NAP).***

Keywords: environment, climate, Sajau coal, Berau Basin

1. Introduction

Palynology is a study of pollen and spore includes the dissemination and the application [1]. Palynology analysis is used to support for depositional environment interpretation especially for terrestrial and transitional deposit [2]. Palynology analysis also used to determine paleoecology, paleoclimate, biostratigraphy, etc. Fossils used in palynology analysis are palynomorphs such as pollen, spore, dinoflagellate cyst, achritarch, etc. [3].

This study aims to determine the depositional time, depositional environment, and paleoclimate during coal deposition in the study area using palynology analysis. To determine the depositional time, it is used Palynology Zonation. To determine the depositional environment, it is used Vegetation Zonation [4]. To determine paleoclimate, it is used *Arboreal Pollen* and *Non-arboreal Pollen*. This study also correlates with several study for Coal of Sajau Formation [5] and [6].

There are 10 coal samples from Sajau Formation are used in this study. All samples are an outcrop sample.

Table 1: Coordinates of Study Area

NO	NAMA SUMUR	N	E	SEAM	FORMASI
1	SJ- A1	585980	260631	A	Sajau
2	SJ-B1	582960.620	289563.46	L	Sajau
3	SJ-C1	583276.44	288214.31	L	Sajau
4	SJ-D1	582960.620	289563.46	K	Sajau
5	S-05	597653	251199	A	Sajau
6	S-001	600,146.80	254,750.20	B	Sajau
7	S-002	601,354.60	254,918.40	B	Sajau
8	S-003	599,026.00	257,468.00	B	Sajau
9	S-004	599,291.00	257,358.00	B	Sajau
10	SG-19	581799.136	289409.36	A	Sajau

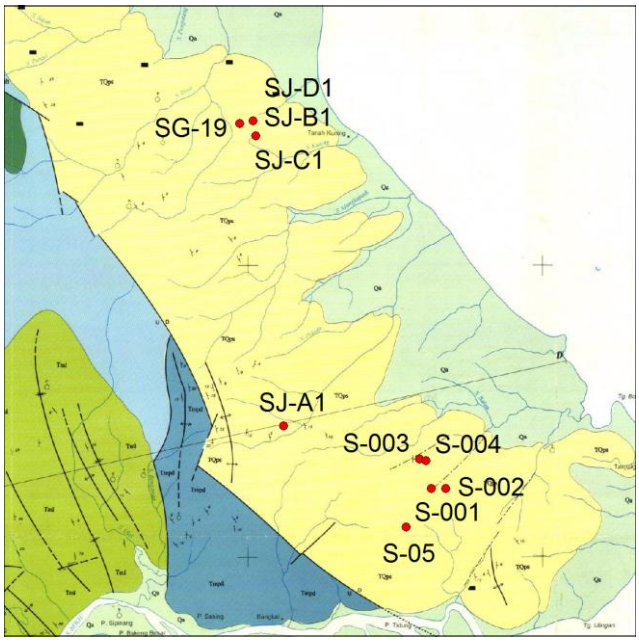


Figure 1. Sample plot in Sajau Formation

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2. Regional Geology

2.1 Regional Tectonics

The Berau Basin is covers onshore areas of the northeast Kalimantan passive continental margin. The basin is bounded to the north by Mesozoic and older rocks of the Sampurna High, to the west by the strongly folded Mesozoic to Eocene mélange of the Kucing High, and to the south by the Mangkalihat High separating the Berau Basin in the north from the Muara Basin and Kutai Basin in the south. This high is regarded as being associated with the Fault Zone along the north shore of the Mangkalihat Peninsula. To east, however, the basin extends toward the Makasar Trough of the Celebes Sea (Figure 2).

The Kalimantan region was a relatively stable Sundaland in the Upper Mesozoic times. Thick flysch sediments derived from erosion of basement highs to the southwest filled the subsiding sites. Intensely folded and faulted sediments in the Upper Cretaceous shifted northwards by Eocene, and resulted in thick siliciclastic deposition in the Tidung Depocentre, with thick mudstone occurred in Berau Basin associated with more stable platform. Tectonics in the northeast Kalimantan area was the result of collision between Indian and Eurasian Plates at 50 Ma. This collision caused the back arc extension related to subduction rollback in the west Pacific, and the opening of the Berau Basin by Rifting in the Eocene. Hall (1996), however, thought that the collision was less significant [7].

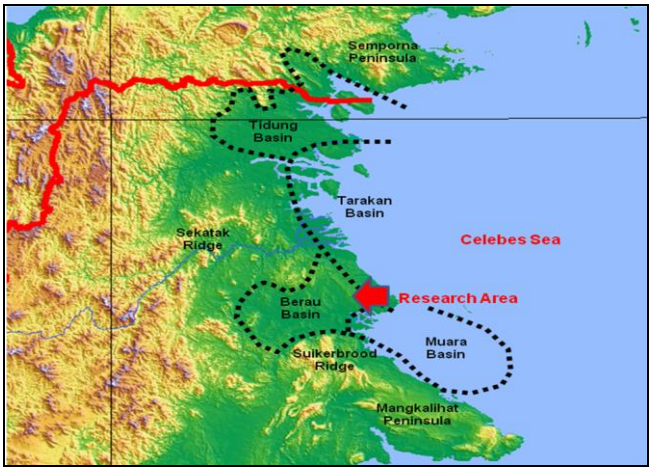


Figure 2: The physiography map of Berau Basin and other basin in Northeastern Kalimantan. There are for basin surrounding the Berau Basin with unique arrangement two onshore and the other two offshore

According to Hutchison (1989) the Tarakan basin is an aulacogen-like basin, with the rifting has likely been related to the complex Eocene tectonic events and plate reorganization that resulted in the opening of the Makasar Strait to the south and the Celebes Sea to the east.

Prior to late Eocene, orogenic uplift of the Sundaland had ended also associated with the slow continuous basinal subsidence marks the beginning of a marine transgression of the Berau Basin. This transgressive deposition extended throughout Oligocene and early Miocene with continued limestone and marl deposition over much of the basin. Renewed tectonic uplift occurred in the western basin margin and highlands the late Oligocene to early Miocene caused siliciclastic, coal and mudstone deposition in the northern basin, whereas limestone deposition continually developed in the stable shelf of the Mangkalihat area to the south.

Two main structural trends are apparent in the Berau Basin, NW to SE and NE to SSW. These trends were initiated in the Eocene, and were periodically reactivated during generally compressive phase from the Middle Miocene to present. Daly et al., (1989) suggested that the regional uplift and inversion in the Middle Miocene was associated with the collision of continental fragments in the South China Sea, whereas an inversion developed in relation to the collision of Australia with the Banda arc in the Pliocene [7]. The Middle Miocene uplift led to deposition of an easterly prograding coarse siliciclastic in the northern Tarakan depocentres. The southern Mangkaliat Peninsula still remained as a submerged limestone platform with the possible beginning of reef build-ups.

The Plio-Pleistocene compression tectonics resulted from fault reactivations and inversions, and a succession of NW-SE plunging oriented anticlines of Tarakan, Bunyu, Latih, and Sebatik anticlines, associated with Kantil and Mandul synclines. In most of the Pleistocene times, sedimentation of the Sajau Formation developed in balance with more rapid subsidence in the Berau Basin. This led to thick deltaic progradational cycles associated with easterly shifted main depocenter from the Tarakan Island. During Pliocene time Mangkaliat area became a positive land area with subsidence of the Muaras dopocentres. Volcanic activity accompanied the renewed uplifting with igneous intrusive and extrusive in the Sekatak and Sadjau areas.

2.2 Regional Stratigraphy

The basin-fill succession of the Berau Basin can be simply divided into 3 (three) major cycles of sedimentation. Every cycle reflects different lithological characteristics, which may have been intimately related to tectonism and related relative sea-level changes leading to transgressive and regressive events (Figure 4). The oldest sedimentary cycle is a syn-rift volcanic bearing siliciclastic-rich unit of the Middle to Upper Eocene which called Sekatak Group consisting of Sembakung Formation and the unconformable overlying Sujau and Malio Formations. The group unconformable overlies pre-rift, Triassic to Cretaceous Sundaland basement rocks, and also underlies the post-rift unconformity below the younger group sediments.

The younger which called Sebuku Group is characterized by transgressive carbonate-bearing units developed during Oligocene-Lower Miocene post-rift transgression. The units consist of Seilor Formation limestone and its lateral equivalent of the Mangkabua Formation. The unconformable overlying rocks are the Tempilan, Tabalar, Mesaloi and Naintupo Formations. Locally regressive sandstone of the uppermost part of Naintupo Formation forming coarsening and shallowing upward facies can be observed in various wells (e.g. Sembakung 6 well). This group is unconformable

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overlain by youngest group, which is characterized by coarser siliciclastic-rich units, with less developed carbonate. The youngest which called Simenggaris Group is divided into five lithostratigraphic units, Meliat/Latih (oldest), Tabul/Domaring, Tarakan/Sajau, and Bunyu (youngest) Formations.

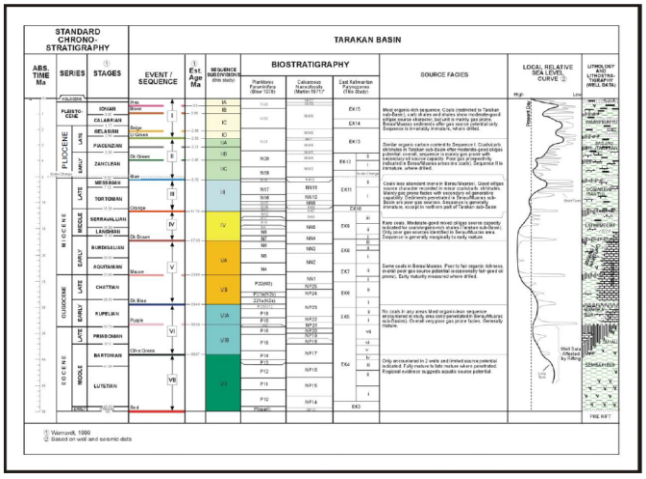


Figure 4: Regional Stratigraphy of Northeastern Kalimantan (Source: Noon et al, 2003. [8])

Sediments of the group were deposited during major regression associated with periods of regional tectonic uplift. Latih Formation is the oldest unit within the youngest group. In Kalmerah-1 well, the unit consists mainly of alternating, sandstone and shale, with coal. In this well, Domaring/Santul Formation conformably overlies Latih Formation and consists of shale, sandstone, and coal. The coal-bearing shale and sandstone of Domaring Formation overlies Meliat Formation, and unconformable underlies Sajau Formation sediments. Tectonic and perhaps eustatic controlled regression continued and led to more proximal sediment deposition of the coarser grained and more developed coal-bearing lithologies associated with thinner shale of the Sajau Formation. The overlying Bunyu Formation is characterized by abundant thick, medium to coarse grained, occasionally conglomeratic sandstone, with lignite interbeds and minor shale.

3. Methods

After choosing ten samples which representative of each coal seam, the next step is sample preparation. Samples were prepared in Pusat Penelitian dan Pengembangan Geologi Kelautan (PPGL) Laboratory, Bandung. After sample preparation, it starts with sample determination and description. For sample determination and description, samples were analyzed under binocular microscope (400x or 1000x Zoom).

The palynomorphs that were found then grouped based on flora vegetation such as peat swamp, freshwater, mangrove, riparian, freshwater swamp, back mangrove, montane, and marine palynomorphs. The palynomorphs also separated between Arboreal Pollen (AP) and Non-arboreal Pollen (NAP). Arboreal pollen is pollen from trees. Otherwise, Non-arboreal Pollen is pollen from non-tree plants. AP/NAP analysis can describe paleoclimate. After finish grouping the palynomorph, the next step is creating diagrams (formulas for taxon diagrams (1) and AP/NAP diagrams (2) and (3)) for helping during analysis.

$$\%\ \mathbf{Taxon} = \frac{\sum \mathbf{Taxon}}{\sum \mathbf{all\ individual}} \mathbf{x\ 100\%} \quad \ldots. (1)$$

$$\%\ \mathbf{AP} = \frac{\sum \mathbf{AP}}{\sum (\mathbf{AP + NAP})} \mathbf{x\ 100\%} \quad \ldots. (2)$$

$$\%\ \mathbf{NAP} = \frac{\sum \mathbf{NAP}}{\sum \mathbf{AP + NAP}} \mathbf{x\ 100\%} \quad \ldots. (3)$$

4. Result and Discussion

4.1 Palynomorph Identification

Based on identification [9, 10, 11, 12, 13, 14], Sample SJ-A1 is deposited in peat swamp (67%) during warm/wet season, dominated with *Retitricolporites sp., Lakiapollis, Haloragacidites harrisii, Cephalomappa, and Elaeocarpus*. There are no marine influence indicates the deposition is in terrestrial environment.

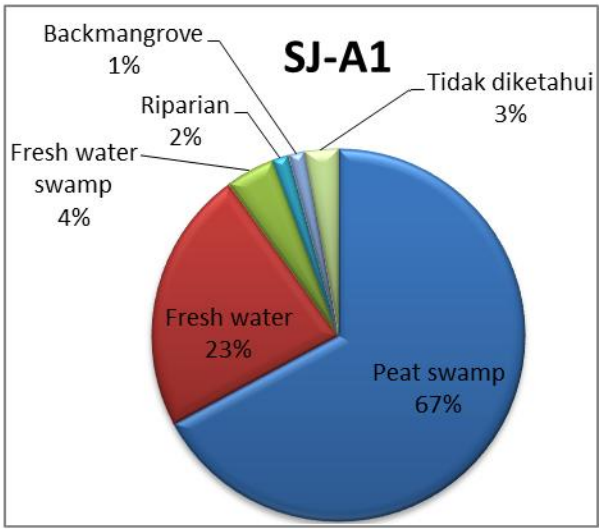


Figure 5: Taxon diagram Sample SJ-A1 based on pollen vegetation

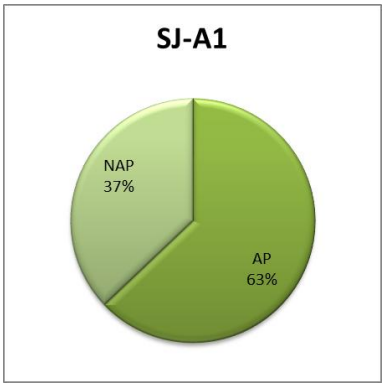


Figure 6: AP/NAP diagram Sample SJ-A1

Sample SJ-B1 is deposited in freshwater (37%) during warm/wet season in Pliocene which the appearance of

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Stenochlaenidites papuanus as marker of Pliocene. The discovery of *Dinoflagellate cyst* (6%) as marine palynomorph indicates that there are marine influences on the deposition (Figure 7) [15, 16].

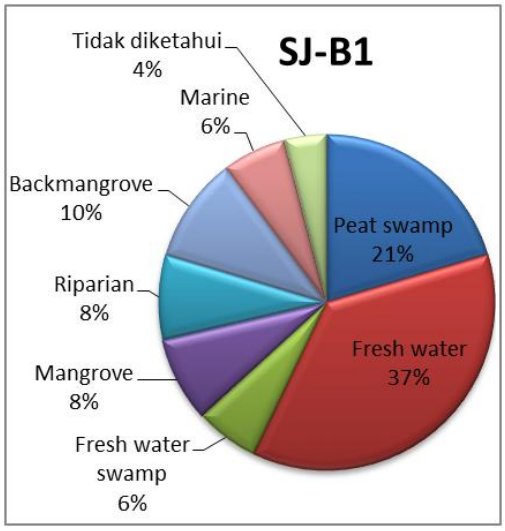


Figure 7. Taxon diagram Sample SJ-B1 based on pollen vegetation

Sample SJ-C1 is deposited in both of freshwater and peat swamp during warm/wet season in Pliocene. The increasing of *Dinoflagellate cyst* (9%) indicates marine influence. Sample SJ-D1 is also deposited in peat swamp (60%) during warm/wet season in Pliocene, but marine influence is decreasing (2%). It indicates that there is still an influence from tide wave.

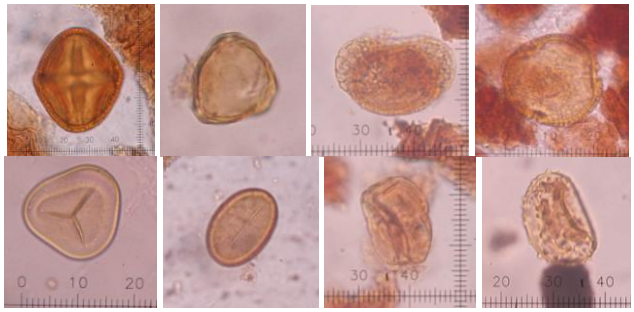


Figure 8. Representative Palynomorph in Sajau Coal: (a) *Retitricolporites sp*.; (b) *Haloragacidites harrisii*; (c) *Lygistepollenites florinii*; (d) *Lanagiapollis microreticulatus*; (e) *Acrostichum aureum*; (f) *Laevigatosporites sp*.; (g) *Stenochlaenidites papuanus*; (h) *Verrucatosporites spp*.

Sample SG-19 is deposited in peat swamp (64%) during cold/dry season in Late Pliocene (The appearance of *Dacrycarpites australiensis and Monoporites annulatus),* dominated with *Meliaceae, Rubiaceae, Lanagiapollis sp., and Sapotaceoidaepollenites.*

Table 2. Palynology Zonation Sample SG-19

NO	NAME	AGE		
		Pliocene		Pleistocene
		Early	Late	
1	*Dacrycarpites australiensis*			
2	*Monoporites annulatus*			

Sample S-001 is deposited in peat swamp (54%) during warm/wet season, dominated by *Lakiapollis sp., Haloragacidites harrisii, Cephalomappa,* dan *Tiliapollenites.* Sample S-002 is deposited in freshwater during cold/dry season.

Sample S-003 is deposited in freshwater (34%) during cold/dry season. The appearance of *Stenochlaenidites papuanus* as marker Pliocene indicates that sample S-003 is deposited in Pliocene. Sample S-004 is deposited in freshwater (38%) during warm/wet season, dominated by *Blechnum indicum, Haloragacidites harrisii, Euphorbiaceae, Verrucatosporites sp., dan Elaeocarpus.* And Sample S-05 is deposited in peat swamp during warm/wet season. Sample S-001, S-002, S-003, S-004, and S-05 are deposited in Pliocene.

4.2 Discussion

The palynomorph that had been found then analyzed to interpret depositional time, depositional environment, and paleoclimate. The analyses also correlate with previous research (Figure 9).

4.2.1 Depositional Time

The coal in Sajau Formation consists of A-M coal seam, but only Seam-A, Seam-B, Seam-K, and Seam-L can be analyzed.

Coal Seam-A represent by SJ-A1, SG-19, and S-05. Based on palynomorph identification, SJ-A1 and S-05 didn't have pollen marker. However, SG-19 is deposited in Late Pliocene (The appearance of *Dacrycarpites australiensis and Monoporites annulatus)*. So, Coal seam-A is deposited in Late Pliocene.

Coal Seam-B represents by S-001, S-002, S-003, and S-004. Coal Seam-K represents by SJ-D1, and Seam-L represents by Sample SJ-B1 and SJ-C1. Based on palynomorph identification, Coal Seam-B, Seam-K, and Seam-L are deposited in Pliocene because of the appearance of *Stenochlaenidites papuanus* as marker.

4.2.2 Depositional Environment

Coal Seam-A is dominated by peat swamp palynomorph (Sample SJ-A1 67%, S-05 43%, and SG-19 64%) and less of mangrove palynomorph (only on Sample S-05 2%), and Coal seam-B is dominated by freshwater palynomorph (S-001 20%, S-002 56%, S-003 34%, and S-004 38%). There is no marine influence. It indicates that Seam-A and Seam-B are deposited in fluviatile such as braided river and meandering. After correlate it with previous study (Figure 9), coal Seam-A and Seam-B is deposited in braided river.

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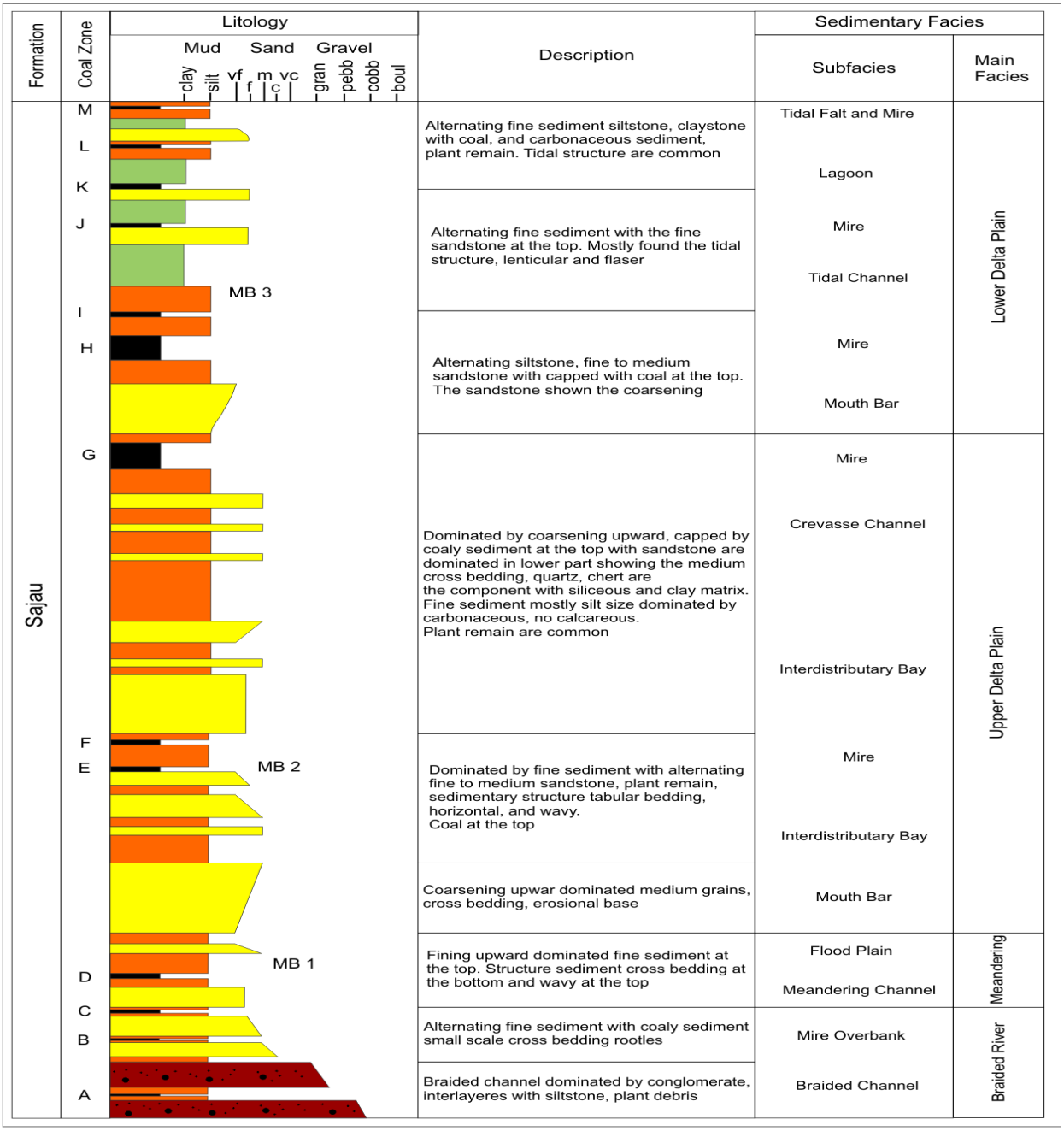


Figure 9: Application of High Resolution Sequence Stratigraphy to the Sajau (Pliocene) Coal Distribution in Berau Basin, Northeast Kalimantan (Source: A. H. Hamdani, 2013, Unpublished Report [5]

Coal Seam-K is dominated by peat swamp palynomorph (60%) and Seam-L is dominated by freshwater palynomorph (SJ-B1 37% and SJ-C1 34%) and there are marine influences (the appearance of *Dinoflagellate cyst*). It indicates that coal Seam-K and Seam-L are deposited in transition depositional environment such as delta. Based on, delta classification by Morley (1990), coal Seam-K and Seam-L are deposited in lower deltaic plain. And after correlate with previous study, coal Seam-K and Seam-L are deposited in lower deltaic plain. After correlate with previous study, Seam-K and Seam-L are deposited in lower deltaic plain.

4.2.3 Paleoclimate

For Sajau Formation, there are three period of climate [17, 18]. First, Coal Seam-A is deposited in warm/wet season. After that, it changes to cold/dry season in Coal Seam-B. And, it changes into warm/wet season when the deposition of Coal Seam-K and Seam-L.

Coal Seam-A represent by SJ-A1, SG-19, and S-05. Sample SJ-A1 has AP 63% and NAP 37%, SG-19 have AP 37% and NAP 63%, and S-05 have AP 56% and NAP 44%. In conclusion, Seam-A is deposited during warm/wet season.

Coal Seam-B represent by S-001, S-002, S-003, and S-004. Sample S-001 have AP 53% and NAP 47%, S-002 have AP 40% and NAP 60%, S-003 have AP 37% and NAP 63%, and S-004 have AP 54% and NAP 46%. In conclusion, Seam-B is deposited during cold/dry season.

Coal Seam-K represent by SJ-D1 (AP 70% and NAP 30%). Coal Seam-L represent by SJ-B1 and SJ-C1 (SJ-B1 have AP 59% and NAP 41%, and SJ-C1 have AP 60% and NAP

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40%). Both of Seam-K and Seam-L are deposited during warm/wet season.

5. Conclusion

Pollen analysis results indicate that during the process of coal formation occurred in Sajau Formation was deposited in a variety of different depositional environments and are influenced by climate change. Coal seam A and B which is the lowest part of Sajau Formation deposited in fluviatile environment with no marine influence during warm to dry conditions; while coal seam K and L which is the top Sajau Formation was deposited in a lower deltaic environment where marine influence is significant during warm/wet seasons.

References

[1] Hyde, H.A.; D.A. Williams (1944). "The Right Word". *Pollen Analysis Circular* **8**: 6
[2] Boggs, S., 1995. Principles of Sedimentology and Stratigraphy. Prentice Hall, Inc., Simon and Schuster Company, Upper Saddle River, New Jersey, Second Edition.
[3] Traverse, A, 1988. *Paleopalinology.* Department of Geosciences, College of Earth and Mineral Sciences, the Pennsylvania State University. Boston
[4] Haseldonckx, P., 1974. *A Palynological Interpretation of Paleoenvironments in Southeast Asia*. Robertson Research. Singapore.
[5] Helman, A. H. 2013. The Application of High Resolution Sequence Stratigraphy to the Sajau (Pliocene) Coal Distribution in Berau Basin, Northeast Kalimantan. Unpublished Report.
[6] Helman, A. H. and Edy Sunardi. 2014. Sedimentology and Petrography of Sajau Coal Formation in Berau Basin, East Kalimantan, Indonesia. International Journal of Science and Research.
[7] Hall, R., 1996. Reconstructing Cenozoic S.E. Asia. In: Hall R. and Blundell D. (eds.) 1996. Tectonic evolution of Southeast Asia, Geological Society Special Publication no. 106, p. 153-184
[8] Noon Stephen, John Harrington, Herman Darman, 2003, The Tarakan Basin, East Kalimantan : Proven Neogene Fluvio-deltaic prospective Deep Water and Paleogene Plays in A Regional Stratigraphic, Proceedings Indonesian Petroleum Association, 29th Anniversary Convention, Vol. 1, p. 241-253
[9] Erdrtman, G. 1966. Morphology and Taxonomy Angiospermae. The Botanica Company Wather Massachusetts. USA.
[10] Huang, Tseng-chieng. 1972. Polen Flora of Taiwan. Department of Botany, National Taiwan University. Taipei, Taiwan.
[11] Huang, Tseng-chieng. 1972. Spora Flora of Taiwan. Department of Botany, National Taiwan University. Taipei, Taiwan.
[12] Moore, P. D. and Webb, J. A. 1978. An Illustrated Guide to Pollen Analysis. Hodden and Stoughton. London.
[13] Morley, R. J. 1990. Introduction to Palynology (With Emphasis on South East Asia). Unpublished Report.
[14] Hesse, Michael, et, al. 2009. Pollen Terminology. Springer Wien New York. Austria.
[15] Demchuk, Thomas and Timothy A. Moore. 1993. Palynofloral and Organic Characteristics of Miocene bog-forest, Kalimantan. Indonesia. Pergamon Press Ltd.
[16] Haq, Bilal U. dan A. Boersma. 1984. Introduction to Marine Micropaleontology. Elsevier Science Publishing Co., Inc. USA
[17] Csurches, S. and R. Edward. 1998. Potential Environmental Weeds in Australia. Queensland Department of Natural Resources.
[18] Morley, R. J. Palynological Evidence for Tertiary Plant Dispersals in the SE Asian Region in Relation to Plate Tectonics and Climate. Edited by Robert Hall and Jeremy D. Holloway. 1998. Backbuys Publisher, Leiden, the Netherlands.

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