



Palaeoenvironmental Interpretation of the Upper Triassic Baluti Formation in two selected sections at Amediya District, Kurdistan Region- Iraq: Insights from Palynofacies Study

Nahida M. Azo^{1*}, Majeed T. Hanna², Ayad N. F. Edilbi¹

¹ Department of Petroleum Geosciences, Faculty of Science, Soran University, Soran, Kurdistan Region- Iraq.

² Department of Geology, College of science, University of Salahaddin, Erbil, Kurdistan Region- Iraq.

*Corresponding author's email: Nahida.azo@Soran.edu.iq

Article info	Abstract
Original: 3 November 2019 Revised: 7 December 2019 Accepted: 30 January 2020 Published online: 20 June 2020 Key Words: <i>Baluti Formation</i> <i>Kurdistan Region</i> <i>Palynofacies</i> <i>Depositional Environment</i> <i>Sedimentary Organic Matter</i>	Palynofacies analysis was carried out on 28 outcrop samples from the Upper Triassic Baluti Formation from Zewa and Sararu Sections in south and northwestern of Amediya District respectively, Kurdistan Region- Iraq. Based on the studied palynofacies, both sections are quite different in terms of depositional environment. Four types of palynofacies were recognized as following: the palynofacies type IV (Pl.1) is observed in the lower, middle and upper portions of upper part of Zewa Section in which, is characterized by high amount of phytoclasts, medium percentage of amorphous organic matter (AOM) and palynomorphs. This facies is referred to a depositional area that is located relatively nearshore with an arid hinterland, the palynofacies type V (Pl.2) was observed in lowermost and middle portions of upper part of Zewa Section, which is characterized by high domination of palynomorphs (mainly bisaccates and monosaccate pollen grains) and a less amount of phytoclasts and AOM. This facies indicates the domination of shallow marine to continent environment. The palynofacies type VI (Pl.3) was observed in middle and upper portions of upper part of the Zewa Section and lower and upper parts of the Sararu Section. This facies showed less amount or absence of palynomorphs, and relatively high amount of AOM and phytoclasts. In addition to this, a remarkable percentage of dinoflagellate cysts in Sararu Section has been found in this facies. This facies indicates proximal suboxic-anoxic shelf, and palynofacies type IX (Pl.4) was observed in middle to upper part of Sararu Section and characterized by less amount or absence of palynomorphs with high amounts of AOM and phytoclasts, which represents a deep environment of deposition.

1. Introduction

The studied area is located in Kurdistan Region- Northern Iraq. The Sararu Section is located in northwest of Amediya Town within southern limb of Ora Anticline at latitude 37°14'55.35" N and longitude 43°17'50.38" E, and the Zewa Section is located in south of Amediya Town within Gara Anticline at latitude 36°59'46.56" N and longitude 43°28'41.21" E (Fig.1).

The Baluti Formation was first introduced by Wetzel in [22] and emended by Morton in 1951 (in [5]). The name of the formation is derived from Baluti Village (Baluti type section), which is located in the southeastern Amadiya, Kurdistan Region-Iraq [6]. The reported thickness of the formation is around 35-60

m at the outcrops. In its type locality section, it generally consists of alternation of thin shale and thin to medium beds of carbonates. The formation within Gara Anticline is thinning westwards [13].

From the early 1959, Jan Muller (in [21]) realized that the distribution patterns of palynomorphs and other particulate organic matter (POM) can be used for recognition of facies and paleogeographic reconstructing. [8] First introduced the term palynofacies as the total complement of acid-resistant particulate organic matter recovered from sediments by palynological processing techniques. Palynofacies is a term used in paleopalynology for the assemblage of palynomorphs taxa in a body of sediment, representing local environmental condition and not typical of the regional palynoflora [18]. Powell *et al.*, [16], defined palynofacies as distinctive assemblage of particular organic matter present in sediments and insoluble in acids (HCl & HF). The aim of this study is to determine the palaeoenvironment of deposition of Baluti Formation by using 28 samples from (Zewa and Sararu) sections (Fig. 1).

In this study, the sedimentary organic matter groups were separated from the sediments, each category (palynomorphs, phytoclasts, and amorphous organic matter) were counted, and accordingly their distribution was calculated to find the percentage of each group. The palaeoenvironmental interpretations presented here are mainly depending on the quantitative (semi-quantitative) palynofacies characteristics of selected constituents of the palynological matter, which are known to have a palaeoenvironmental significance. The previous studies on the Baluti Formation are:

Hanna [10] suggested the prevalence of shore zone depositional environment with influence of fresh water for the lower portion of upper part of the Baluti Formation. Al-Ameri *et al.* [2] suggested the distal coastal marine environment for the Baluti Formation. Mustafa [14]'s suggestion is that shale sediments of the Baluti Formation were deposited in an oxic shallow marine environment under warm and humid climate. Akram [1] studied the palynofacies and source rock evaluation of Baluti Formation in both Atrush-1 and Sheikhan-1B wells. He suggested the shallow oxic marine palaeoenvironment for the formation. Edilbi *et al.* [9] studied the Baluti Formation at Sararu Village, they believed that the age of studied section is probably Upper Cretaceous to Lower Tertiary, thus the studied unit cannot be considered as the correlative Triassic Baluti Formation.

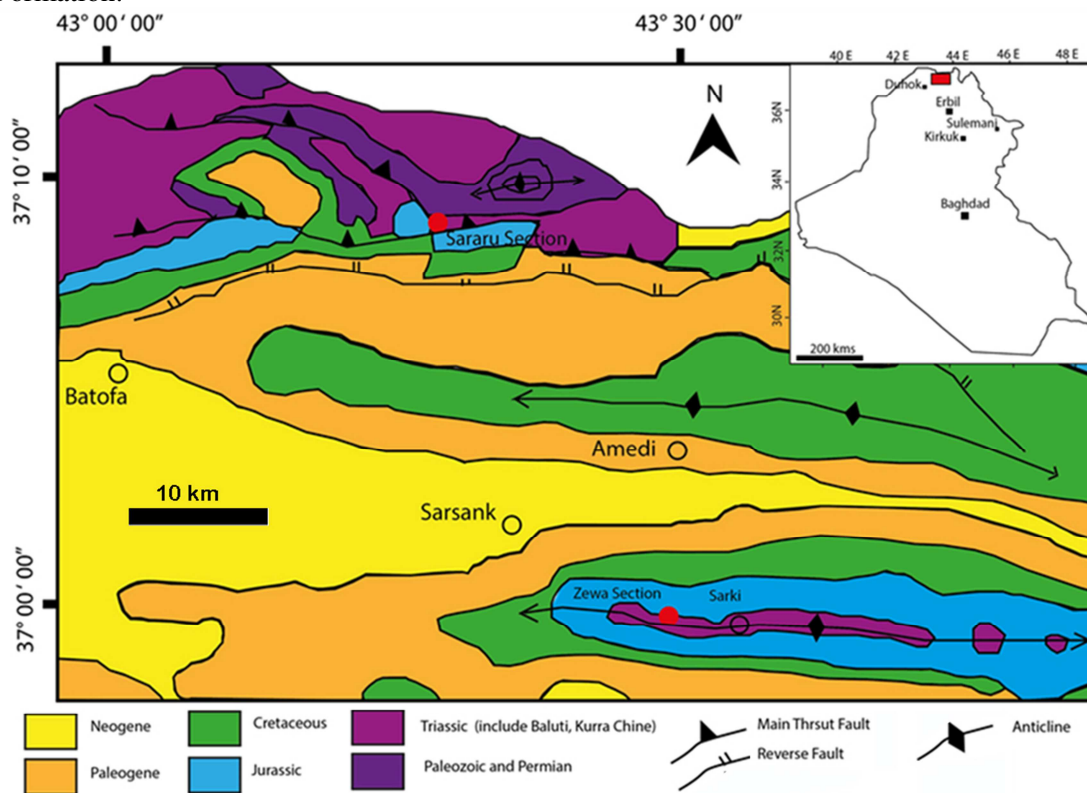


Figure 1: Geological map of Iraq and the location of the studied sections (after [17]).

1.1. Geological Setting

The Baluti type section is regionally located within the Zagros Fold Belt and locally within the High Folded Zone of Iraqi tectonic division [12]. Stratigraphically, the formation is underlain by Kurra Chine

Formation and overlain by Sarki Formation. Bellen *et al.* [5] stated that both lower and upper contacts of the formation are conformable except in well Tharthar-1. However, in view of the apparent stratigraphic break between the Triassic and Jurassic in Saudi Arabia and SW Iran, the upper contact of the formation in Western Iraq needs further study [12]. According to the Hanna [10] study, the Triassic-Jurassic boundary is located between Baluti and Sarki formations. Accordingly, the nature of the boundary appears to be unconformable, due to the age missing, which is represented by Norian-Rhaetian and possibly Early Liassic. The formation was suggested to be deposited in lagoonal-evaporitic and estuarine environments [13]. Buday [6] assumed that the Zor Huaran Formation is tentatively equivalent with the Baluti Formation in Western Iraq. In Syria, the formation may be equivalent to the “Mulussa-F” unit of Palmyrides and SE Syria [12].

According to the tectonic map of Jassim and Buday [12], Sararu section crops out at the Northern Thrust Zone of Iraq near the Iraqi-Turkish border and Zewa Section is located in the High Folded Zone south of Amediya Town (Fig.2).

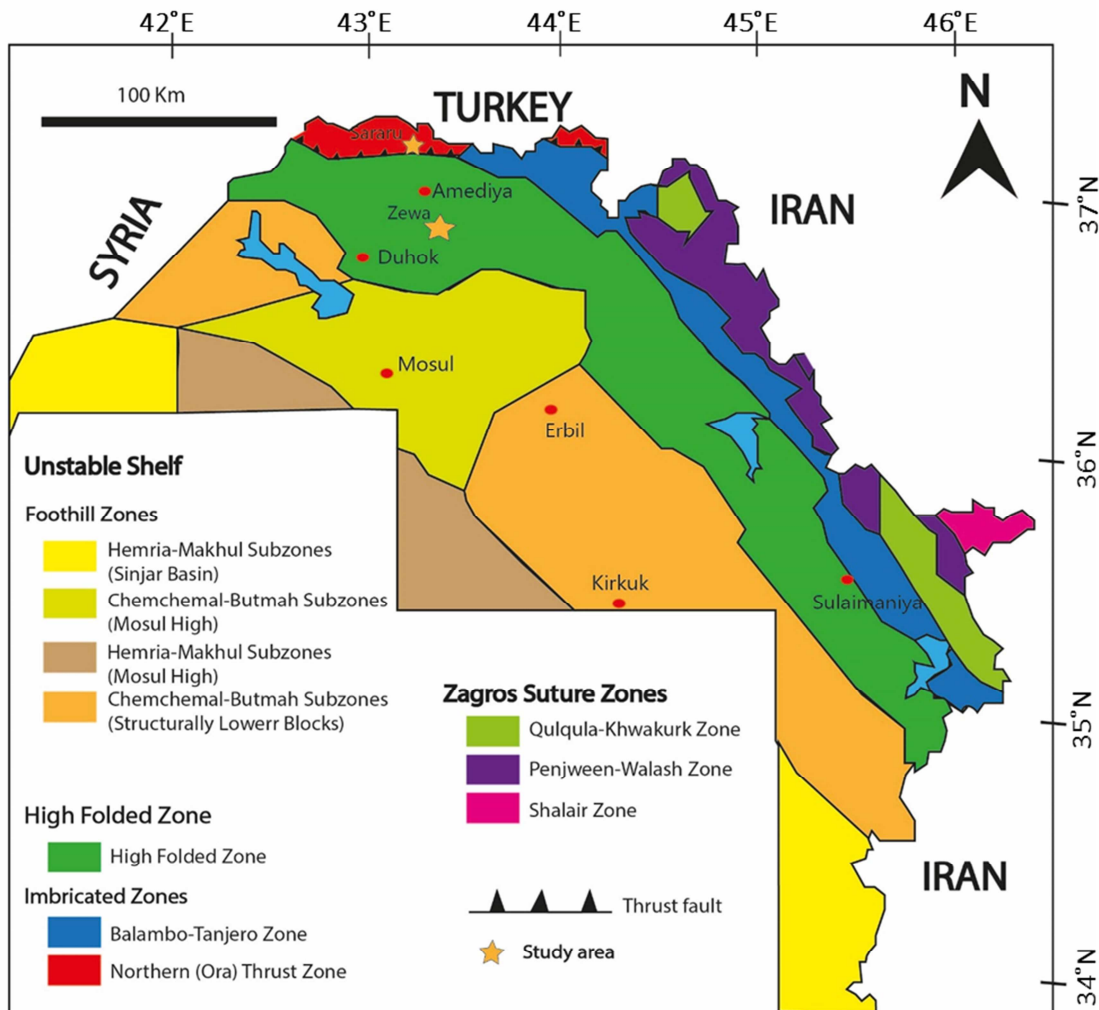


Figure 2: Tectonic map of N-Iraq showing the location of the studied area (after [12]).

1.2. Methods and Materials

In the current study, 28 outcrop samples were selected for palynofacies analysis. The palynofacies slides were prepared at the Department of Petroleum Geosciences, Faculty of Science-Soran University and Department of Geology, College of Science- Salahaddin University-Erbil. The procedure of samples preparation was followed the standard palynological techniques without oxidation or ultrasonic treatments of Tyson [21], Batten & Stead [4], and Carvalho *et al.* [7]. The investigated material was prepared for palynofacies analysis following standard extraction techniques: matrix of the sample treated with HCl and HF to remove the carbonate and silicate materials respectively, without any oxidation and then the residue

was sieved through 10 µm nylon mesh. Thereafter, materials mounted on glass slides by using cellosize and Canada balsam as mounting media.

The samples were studied under a transmitted light microscope (Leica DM 2700P), the photomicrographs were taken with Leica DFC 295 (12730469) at microscopic laboratory of the Scientific Research Center (SRS)-Soran University. The quantitative analysis of the POM was based at least on the first (250) palynomorphs, phytoclasts and amorphous organic matters counted for each sample as shown in table-1. The counting was carried out at X200 magnification. The classification of Tyson [21] was used for determination of palaeoenvironmental interpretation.

2. Results and Discussion

The percentages of the components are shown in (Table 1). It is clearly seen that the most dominated components of Sararu Section were the amorphous organic matter (sponge AOM), and has various percentages of phytoclasts (brown, structured- leaf and membranous and fungal hypha phytoclast), palynomorphs (some dinocysts, few chitinozoans) (Plate II); however, in Zewa Section the major component of palynomorphs were spores and pollen grains, some prasinophytes, chlorococcalean algae and foraminiferal test lining with medium amounts of phytoclasts (brown, structured- leaf and membranous phytoclast) and amorphous organic matter (resin particle and sponge AOM) (Plate I).

Table 1: Percentages of different organic matter in Sararu and Zewa Sections

<i>Section</i>	<i>Sample No.</i>	<i>Palynomorphs</i> %	<i>Phytoclasts</i> %	<i>Amorphous Organic Matter (AOM)</i> %
<i>Sararu</i>	<i>BS-1</i>	3	40	57
	<i>BS-2</i>	4	46	50
	<i>BS-3</i>	8	40	52
	<i>BS-4</i>	1	39	60
	<i>BS-5</i>	1	42	57
	<i>BS-6</i>	2	29	69
	<i>BS-7</i>	0	23	77
	<i>BS-8</i>	0	42	58
	<i>BS-9</i>	6	22	72
	<i>BS-10</i>	1	17	82
	<i>BS-11</i>	12	26	62
	<i>BS-12</i>	1	42	57
<i>Zewa</i>	<i>BZ-1</i>	52	28	20
	<i>BZ-2</i>	52	20	28
	<i>BZ-3</i>	51	20	29
	<i>BZ-4</i>	32	45	23
	<i>BZ-5</i>	22	36	42
	<i>BZ-6</i>	8	35	57
	<i>BZ-7</i>	14	31	55
	<i>BZ-8</i>	28	45	27
	<i>BZ-9</i>	60	21	19
	<i>BZ-10</i>	74	18	8
	<i>BZ-11</i>	7	50	43
	<i>BZ-12</i>	20	44	36
	<i>BZ-13</i>	5	40	55
	<i>BZ-14</i>	2	36	62
	<i>BZ-15</i>	4	47	49
	<i>BZ-16</i>	12	52	36

Note: BS (Baluti Formation- Sararu Section), BZ (Baluti Formation- Zewa Section).

At **Sararu Section**, the base of the formation begins with alternating grey marlstone with dark grey dolomitic limestone. Middle part is mostly composed of dark grey calcareous shale with thin layers of dolomitic limestone, while the upper part of formation is dominated by dark grey calcareous shale, dark grey marlstone and dark grey well-bedded dolomitic limestone. The thickness of Baluti Formation in this section is around 110.5 m (Fig.3). At **Zewa Section**, the lower part of the Baluti Formation in type section is not

exposed, the lower portion of the upper part mostly dominated by varied thickness of black shale and grey marlstone with thin layer of dolomite. The middle portion is characterized by relatively thicker beds of black shale in comparison to the lower portion. These beds are alternated with thin layers of buffy dolomite. The upper portion of the upper part of formation is commonly composed of dolomitic limestone and black shale, which characterized by intercalation between light olive-green shale and buff-colored dolomitic limestone and dark brown intraclasted limestone that arranged in a rhythmic system. Each cycle started with shale, then light grey dolomitic limestone and finally dark brown limestone. The uppermost layers composed of light olive green of marlstone with thin layer of limestone and marly limestone. The thickness of Baluti Formation in this section is 41.6 m (Fig.4)

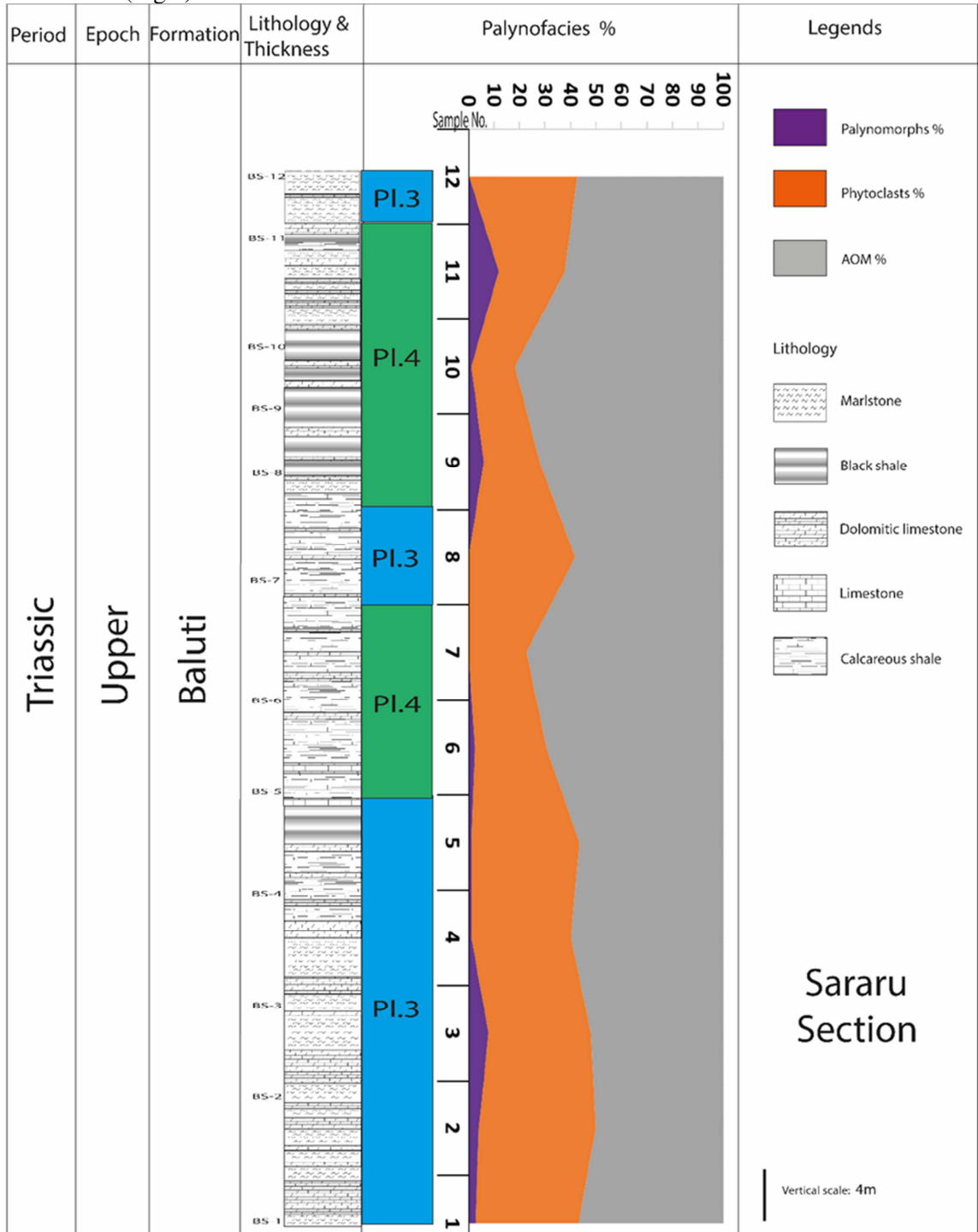


Figure 3: Stratigraphical column and palynofacies of Baluti Formation based on the percentages of different organic matters in Sararu Section.

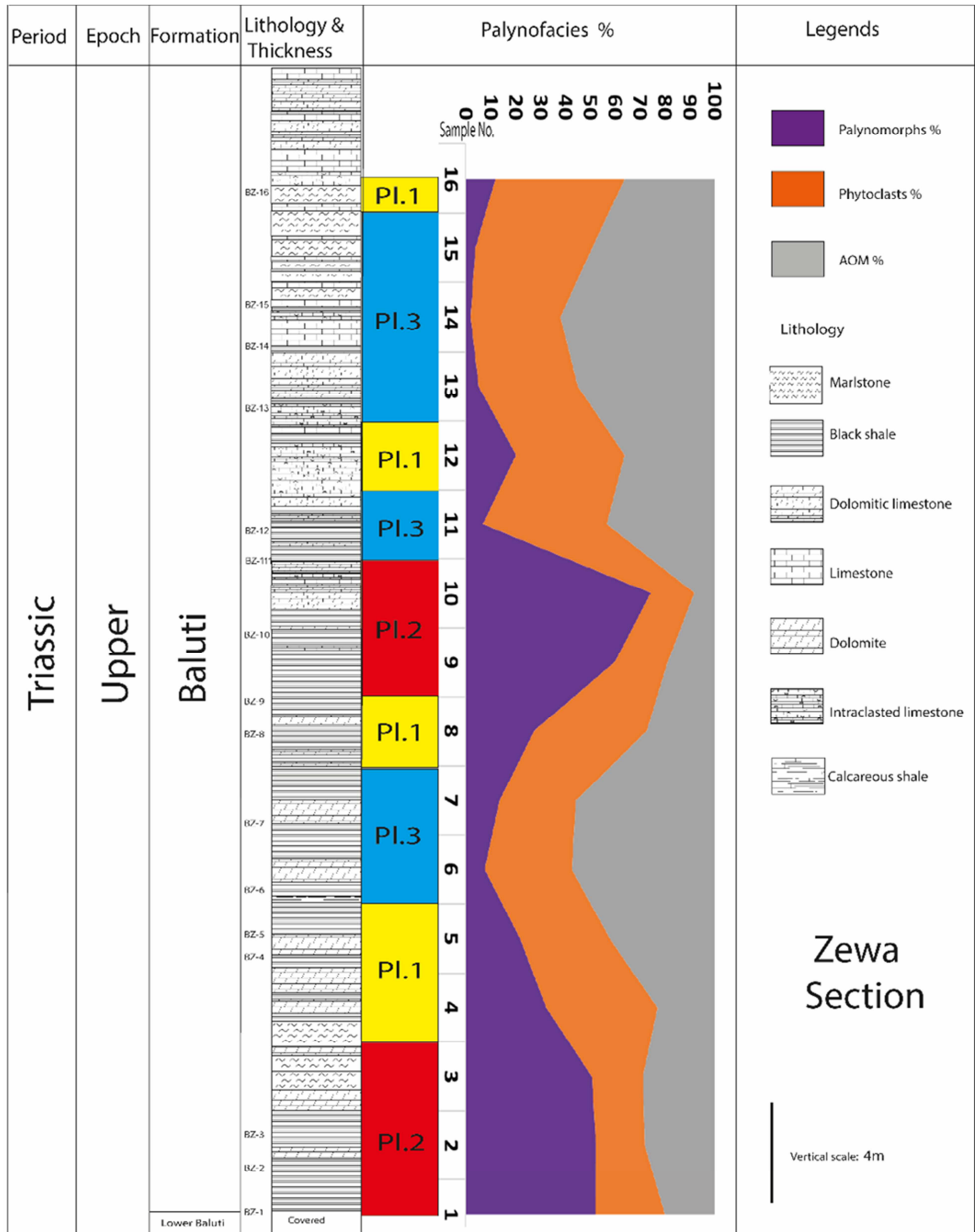


Figure 4: Stratigraphical column and palynofacies of the Baluti Formation based on the percentages of different organic matter in Zewa Section.

Four distinctive palynofacies were identified based on the estimated percentage amount of each organic matter categories and the lithology of the host sediments (Figs.3 and 4). Then each palynofacies were plotted on Tyson (1995) ternary diagram to determine depositional environment, the type of kerogen and their production capability (Fig.5A-B), (see Table 3).

Palynofacies Type IV (PI.1) was observed only in Zewa Section at its upper part of lower portion, middle and upper portions (samples BZ. 4, 5, 8, 12, and 16). This palynofacies is characterized by presence of

palynomorphs (12-32%), phytoclasts (36-52%), and AOM (23-42%), the palynomorphs mainly composed of bisaccates and monosaccate pollen grains, few foraminiferal test lining and rare spores. (Plate I, h). The spore plants are usually bound to more humid climates [21]; thus, a depositional area is located relatively nearshore with an arid hinterland. This palynofacies according to the ternary diagram of Tyson (1995), which is suggested to be deposited in shelf to basin transition, similar to Abtalkh Formation in eastern Koppeh-Dagh basin of Iran by Allameh and Nejad [3] and Baluti Formation in both Atrush-1 and Sheikhan-1B wells [1]. This might be due to increase of the accommodation space, which was caused by subsidence of the basin or increasing of water depth. Phytoclast abundance depends on proximity to source and degree of redeposition and moderate to high abundance of palynomorphs. This facies assumed to be kerogen type III or II that is prone to generate mixed gas and oil [21] (Fig.5A) (Plate III).

Palynofacies Type V (Pl.2) was observed only in Zewa Section at its lower and middle portions (samples BZ.1, 2, 3, 9, and 10). This palynofacies is characterized by presence of palynomorphs (51-74%), phytoclasts (18-28%), and AOM (8-29%), the palynomorphs mainly composed of bisaccates and monosaccate pollen grains. (Plate I, i-k). The increasing of palynomorphs indicates the domination of shallow marine to continental environment due to influx of transported continental palynomorphs. This palynofacies characterized by mud-dominated oxic shelf (distal shelf), with low to moderate AOM (usually degraded), and high abundance of palynomorphs. This facies assumed to be kerogen type III>IV that is prone to generate gas [21] (Fig.5A) (Plate III). Similar result for Atrush-1 and Sheikhan-1B Wells of Baluti Formation [1].

Palynofacies Type VI (Pl.3) this palynofacies is clearly seen at middle and upper portions of the Zewa Section (samples BZ.6, 7, 11, 13, 14, and 15) and lower and upper parts of the Sararu Section (samples BS.1, 2, 3, 4, 5, 8, and 12). This palynofacies is characterized by presence of palynomorphs (0-14%), phytoclasts (31-50%), and AOM (43-62%). In Sararu Section, the amount of phytoclast and AOM are nearly the same. This palynofacies type indicates proximal suboxic-anoxic shelf, with high AOM preservation due to reducing basin conditions similar to Abtalkh Formation in eastern Koppeh-Dagh basin of Iran by Allameh and Nejad [3] and Naokelekan Formation of North Iraq from the palynofacies study of Isamel and Orhan [11]. Absolute phytoclast content may be moderate to high due to turbiditic input and/or general proximity to source in this facies. Presence of dinoflagellate cysts (Plate II, e and f) at Sararu Section may exhibit offshore increase with increased water depth ([19], [20]). This facies assumed to be kerogen type II that is prone to generate oil [21] (Fig.5A, B) (Plate III).

Palynofacies Type IX (Pl.4) was observed only in middle and upper parts of Sararu Section (samples BS.6, 7, 9, 10, and 11). This palynofacies is characterized by presence of palynomorphs (0-12%), phytoclasts (17-26%), and AOM (62-82%). This palynofacies indicates a deeper environment of deposition (distal suboxic- anoxic basin), as in the Çanakkale-Çan Basin (NW Turkey) [15]. IX is described as AOM dominated assemblages, low abundance of palynomorphs partly due to masking. Frequently alginate-rich deep basin or stratified shelf sea deposits, especially sediment starve basin. This facies assumed to be kerogen type II>I, which is prone to generate oil [21] (Fig.5B) (Plate III).

Table 2: key to marine palynofacies fields for amorphous organic matter, palynomorph, and phytoclast (APP) diagram [21].

Palynofacies fields and environment		Description	Spores: Bisaccates	Microplankton	Kerogen types
I	Highly proximal shelf or basin	High Phytoclasts supply dilutes all other components.	Usually High	Very low	III (gas prone)
II	Marginal dysoxic-anoxic basin	AOM diluted by high Phytoclasts input, but AOM preservation moderate to good. Amount of marine TOC dependent on basin redox state and dilution.	High	Very low	III (gas prone)
III	Heterolithic oxic shelf (Proximal shelf)	Generally low AOM preservation; absolute Phytoclasts abundance dependent on actual proximity to fluvial-deltaic source. Oxidation and reworking common.	High	Common to abundant Dinocysts dominant	III or IV (gas prone)

IV	Shelf to basin Transition	Passage from shelf to basin in time (e.g.: increased subsidence/water depth) or space (e.g.: basin slop). Absolute Phytoclasts abundance depends on proximity to source and degree of redeposition. Amount of TOC depends on basin redox state.	Moderate to high	Very low-low	III or II (mainly gas prone)
V	Mud-dominated oxic (distal) shelf	Low to moderate AOM (usually degraded). Palynomorphs abundant. Light colored bioturbated, calcareous mudstone are typical.	Usually low	Common to abundant Dinocysts dominant	III>IV(gas prone)
VI	Proximal suboxic-anoxic Shelf.	High AOM preservation due to reducing basin conditions. Absolute Phytoclasts content may be moderate to high due to turbiditic input and/or general proximity to source.	Variable, low to moderate	Low to Common Dinocysts dominant	II (oil prone)
VII	Distal dysoxic-anoxic shelf	Moderate to good AOM preservation, low to moderate palynomorphs. Dark colored slightly bioturbated mudstone are typical.	Low	Moderate to Common Dinocysts dominant	II (oil prone)
VIII	Distal dysoxic-oxic shelf	AOM-dominated assemblage, excellent AOM preservation. Low to moderate palynomorphs (partly due to masking). Typical of organic-rich shales deposited under stratified shelf sea conditions.	Low	Low to moderate Dinocysts dominant, % prasinophytes increasing.	II>>I (oil prone)
IX	Distal suboxic-anoxic basin	AOM-dominated assemblage, low abundance palynomorphs (partly due to masking). Frequently alginite-rich. Deep basin or stratified shelf sea deposits, especially sediment starved basins.	Low	Generally low, prasinophytes often dominant.	II>I (highly oil prone)

NOTE: IV, V and VI fields are belong to Zewa Section, VI and IX fields are belong to Sararu Section.

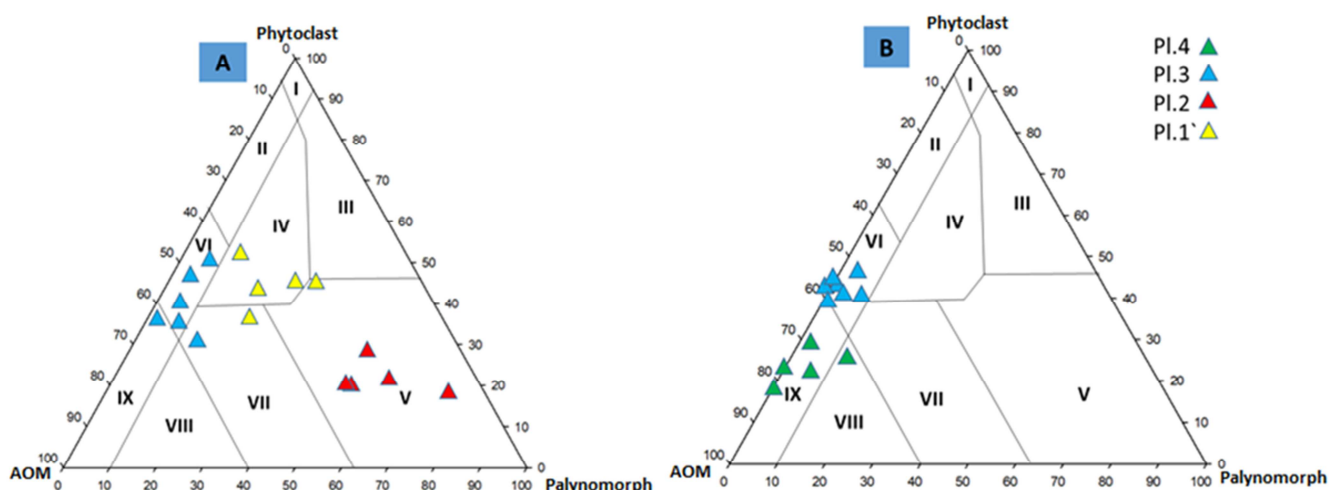
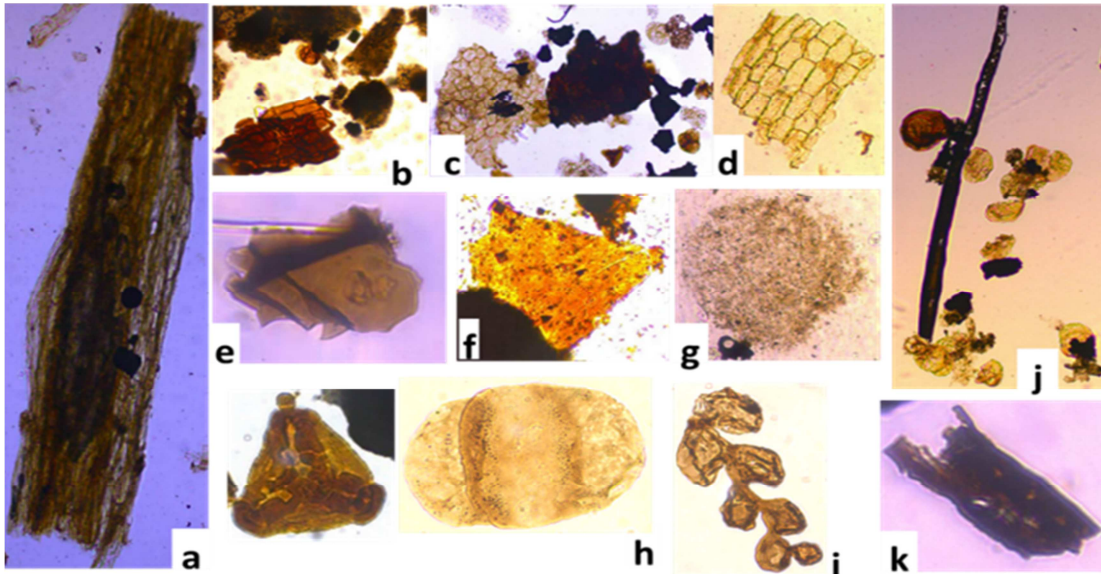


Figure 5. A: amorphous organic matter, palynomorph, and phytoclast (APP) diagram plotted for Zewa Section, which include three distinct palynofacies. B: amorphous organic matter, palynomorph, and phytoclast (APP) diagram plotted for Sararu Section includes two distinct palynofacies for Baluti Formation.

3. Conclusions

Palynofacies analysis shows that the studied sections are quite different in palynomorphs content. The Zewa Section is rich in palynomorphs and the main components are pollen grains, spores and some prasinophytes, chlorococcalean algae and foraminiferal test lining. While, Sararu Section is poor in palynomorphs content (contains some dinocysts, few chitinozoans and fungal hypha), and no spore and pollen grains were observed. Based on the palynofacies analysis the more likely palaeoenvironment for Zewa area is shelf to basin transition and mud-dominated oxic shelf. However, the proposed palaeoenvironment for Sararu area can be distal suboxic-anoxic basin. Due to the remarkable differences in studied sections, we strongly recommend a detailed study of palaeontology, isotope dating, and sedimentology for future studies.

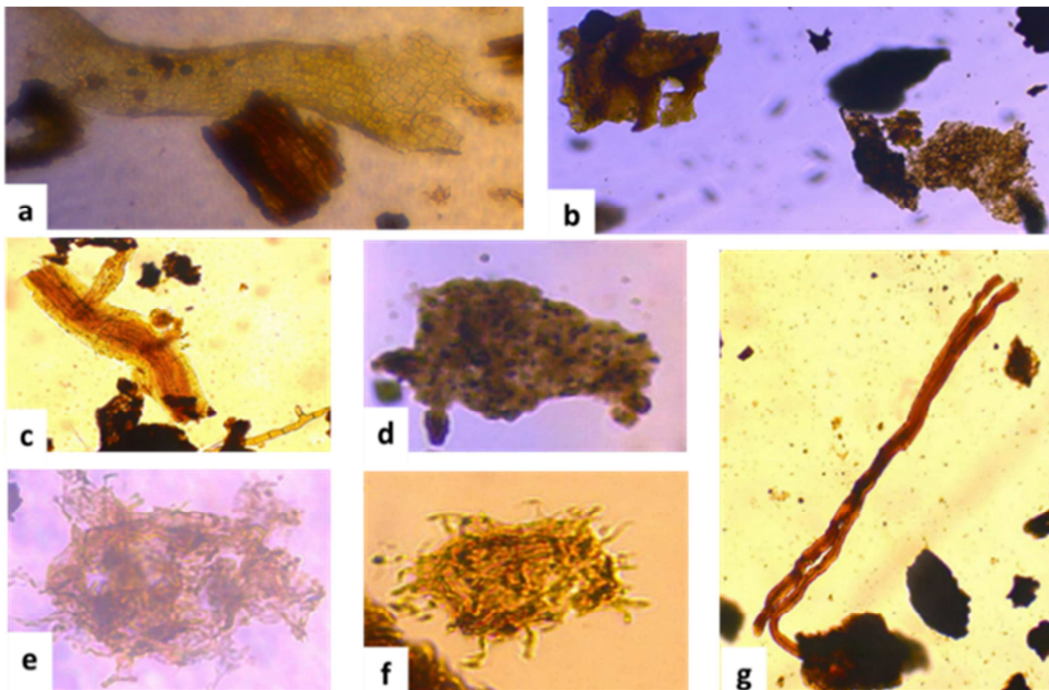
Plate I



Magnification X1000 (a, b, c, d, e, f, g, h, i and k) X200 (j)

Interference light microscope photographs of selected palynomorphs, phytoclasts and AOM from **Baluti Formation in Zewa Section**, **a**) brown, structured phytoclast sample 20, slide 1, **b-d**) leaf and membranous tissue (phytoclasts) in association with terrestrial palynomorphs, samples 9,3,21, slides 1, **e**) AOM particle sample 5, slide 2, **f**) resin particle AOM sample 7, slide 3, **g**) AOM particle sample 19, slide 1, **h**) palynomorphs (bisaccates pollen, trilete spore) samples 3,14, slides 2,1, **i**) biserial foraminiferal test lining samples 14, slide 2, **j**, **k**) biostructured phytoclast samples 11,10, slides 3,2.

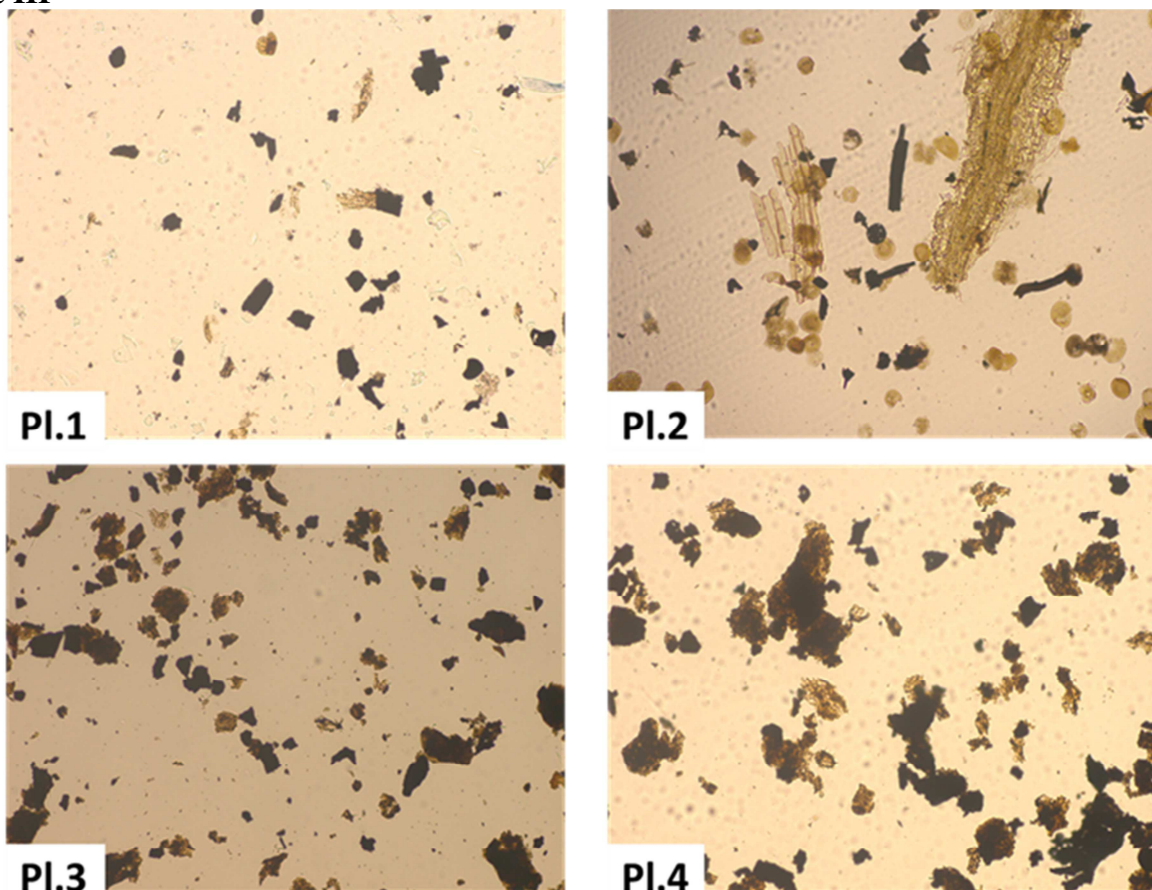
Plate II



Magnification X1000 (a, b, d, e, and f) X400 (c and g)

Interference light microscope photographs of selected palynomorphs, phytoclasts and AOM from **Baluti Formation in Sararu Section**, **a**) leaf and membranous tissue (phytoclasts) samples 12, slides 1, **b**) AOM particles sample 10, slide 1, **c**) brown, structured phytoclast sample 1, slide 1, **d**) AOM particle sample 6, slide 1, **e**, **f**) dinocysts palynomorphs samples 11,4, slides 1,2, **g**) fungal hypha (fragment) sample 3, slide 1

Plate III



Magnification X100

Palynofacies (Pl.1) dominated by brown and black wood, amorphous organic matter and less abundant of palynomorphs.

Palynofacies (Pl.2) dominated by bisaccates and monosaccate pollen grains, brown wood and less abundant AOM.

Palynofacies (Pl.3) dominated by black wood, AOM and less abundant of palynomorphs.

Palynofacies (Pl.4) dominated by AOM and less abundant of phytoclast and dinocysts.

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