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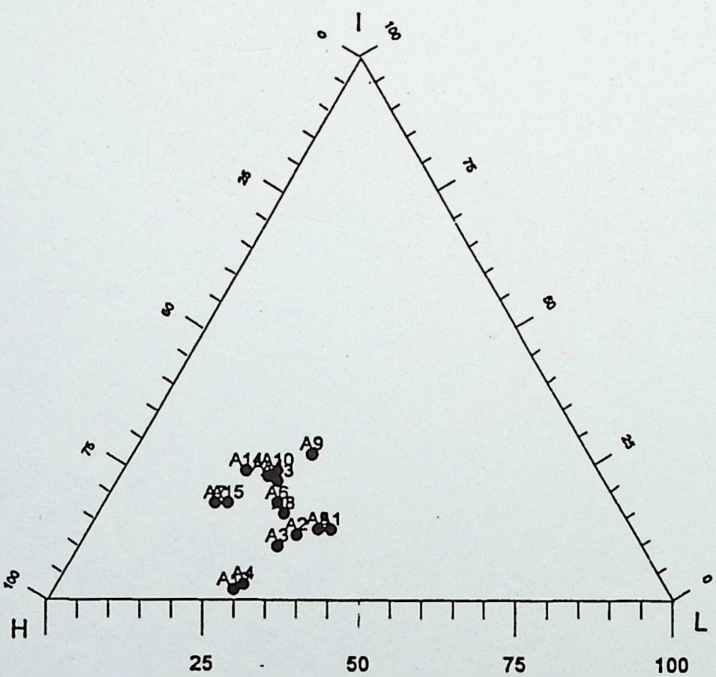

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Greek Browncoals II

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PETROGRAPHIC COMPOSITION AND DEPOSITIONAL ENVIRONMENTS OF THE LIGNITE DEPOSIT OF "APOPHYSI" - AG. ANARGYRI IN NW - GREECE

P. A. ANTONIADIS[1] , H. BLICKWEDE[2] and E. LAMPROPOULOU[1]

Key words : Apophysi, lignite, maceral analysis, reflectance, coal facies diagrams, depositonal environment

Summary

In the pesent paper a sort introduction on the geology of the wider region of Apofysi is given, followed by a detailed description of the lignite beds of a representative borehole. The samples studied were taken from the B-240 borehole. The general picture of the lignite beds on the basis of maceral analysis denotes that this lignite basin did not have a constant geological history but subjected various elevations and subsidences having as a result the differentiation of the lignite beds.

The apparent presence of liptinite denotes higher plants vegetation. The presence of fusinite and semifusinite denotes oxic conditions. The reflectance data measured on the maceral of Eu-ulminite are between 0.22-0.30 and correspond to a coalification stage between peat-lignite.

The presence of clastic matter supports the aspect of a limnic-telmatic environment with continuous offer of clastic matter.

Generally speaking the presence of huminite and liptinite in such high percentages suggest that the deposit is very suitable not only for energy production but also for other uses as for gasification.

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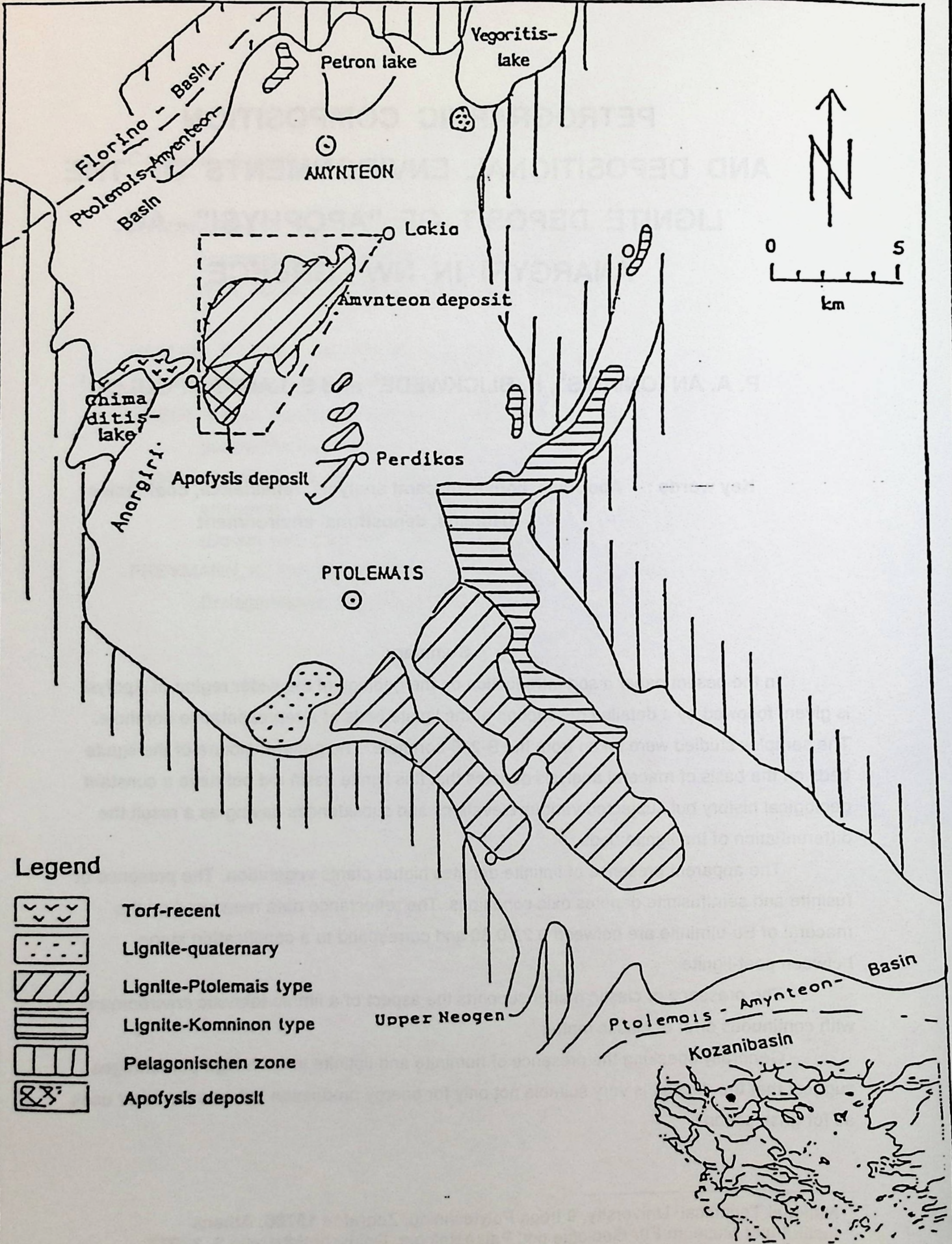


Fig.1: Geological Map according Koukouzas et al. (from P.P.C., Archiv)

Introduction

The major objective of this paper is the study of the lignite deposit of "Apophysi" from a technological point of view using the data analysis results from the study of samples from the B-240 borehole.

Special emphasis will be given to the maceral analysis that expresses the different technological and physical properties of the lignite deposits.

In the present paper an attempt is made to assess the depositional environment of the deposit using coal facies diagrams (recently widely used in literature).

It is apparent that the present paper does not hope to solve the geological problems of the area since they are already studied. It of our special interest though to give detailed macro-microscopically description of the lignite beds.

Analytical procedures

A representative borehole B-240 drilled in the coalfield of Apofysi was sampled. The borehole was drilled in 1993 by I.C.P. as a part of a wider research project of the company, major objective of which is the detailed investigation of the various coalfields all over Greece. The samples taken were mostly small parts of the borehole. During the sampling a detailed description of the lignite seams was carried out, whereas the various formations of the rest of the borehole were identified and recorded (Stach, 1982).

The samples were ground down to 20 mesh and then prepared as blocks using epoxic resin of a moderate rate of setting in order to avoid any possible affect on the rank of the lignites as a cause the heat produced during the exothermic reaction.

All prepared samples were subjected to grinding with 240, 320, 400 and 600 grit papers in that order. After grinding the samples were finely polished with alumina 1ìm on silk cloth.

After the polishing procedure, the petrographic work was carried out which includes the petrographic analysis and the reflectivity measurements. For the depositional environment determination the recently developed diagramms based on maceral analysis were used.

Outline of geology and stratigraphy

The lignite field of Apofysi is a part of the same geological unity that includes Ptolemais coalfield (Fig. 1). Its sequence is disrupted by large scale tectonic movements that took place later during the Quaternary period (Koukouzas et al., 1976). Elongated and deep trenches (like Adrassas-Ptolemais-Begoritidas) and tectonics elevations(like Bordo-Filota) disrupt the sequence of the two lignite basins. The lignite sediments of the area consist part of a thick succession of sediments, that are covered by quaternary terrestrial formations which cover the area of the tectonic deep of Chimaditidas.

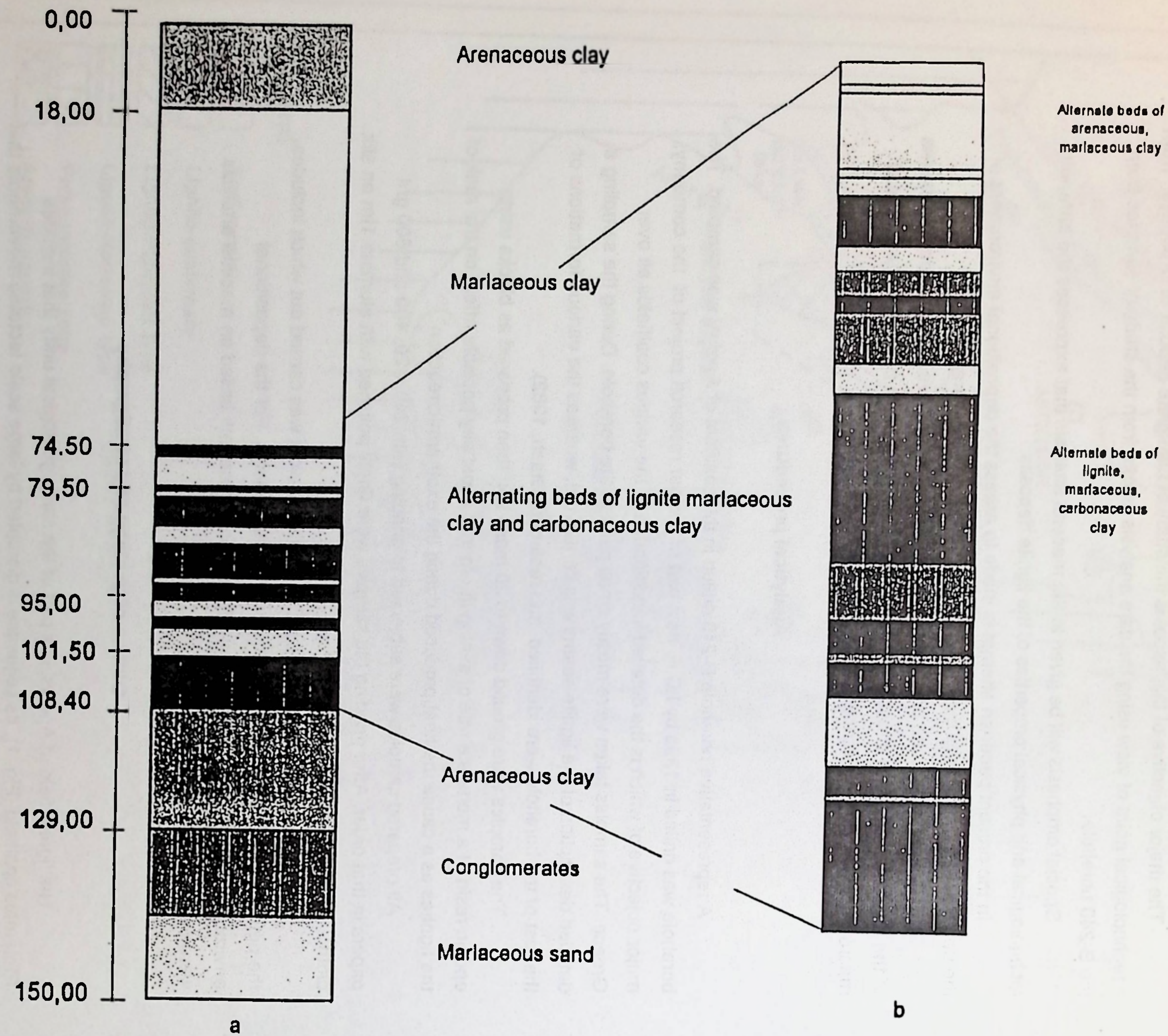


Figure 2. Stromatographic sections of a) the borehole B-240, b) the section where the lignite beds appear (a more detailed section of this part follows

The base and the margins of Ptolemais-Amynteon basin, which is filled by neogenic and quaternary sediments, consists of Premesozoic and Mesozoic formations metamorphosed or not. The western and northern margins (Siniatsiko mount. and surroundings) consist by Palaeozoic and pro-Palaeozoic crystallised rocks, of varied petrographic composition and degree of metamorphism (Koukouzas et al. 1976).

The eastern and Western margins (Vermion mount and surroundings) consist of the formations of the Mesozoic cover of Pelagonic sequence. The major rock formations of the base are crystallised limestones, cherts with ophiolites, on the top of these follow disconformably fossiliferous limestones and on the top of the whole sequence Mestricthian flysche.

The neogen sediments are divided to two discrete seams that differ in the age , the composition and the type of the lignite deposits that comprise. Thus the neogen sediments are separated to lower and upper neogen. The type of lignite that comprise the lower neogen is xylite and the upper lignite. In what it concerns the age of the sediments of the upper neogen according previous works is Pliocene (Koukouzas et al., 1976). For the lower neogen is Lower Pliocene to Upper Miocene, it seems there is continuation between them.

•Lower Neogen

It is the seam that comprises xylite. It consists of sand and clays. It appears on the surface because of the tectonism in the areas of Filota, Lakkia, Bordo, Komnina and Vegora.

•Upper Neogen

It consists of calcareous clays rich in sand and mud. It appears on the surface because of erosion of the quaternary formations. In the area of Filota-Lakkia a seam of limestone rich in the fossils *Planorbis* and *Vivipara* appears. Towards the centre of the basin the limestones turns to marls with the same fossils. A general characteristic of the basin is the marginal transitions from clay to limestone and from clay to sand. The lignite deposits also transit to humic calcareous clays. The single seam that appears consistent is the limestone seam of Ptolemais with *Neritina*.

The quaternary cover almost all the area except the SE part of the deposit where the erosion expose the neogen formations (Koukouzas et el., 1976). During the Pleiostocene severe tectonic movements took place that have as a result the transformation of the basin. The erosion products were deposited on the lower parts. At the same time the transportation and deposition of the products of the erosion the basin was filled by water that flood all the area and form little and big lakes were the newly produced material was deposited.

a. Schimatari formation

It consists of terrestrial formations of boulders sands and red clay.

b. Perdika formation

It consists of fine coarsed sand with intercalation's of sandy clay, marls and conglomerates of minor thickness

c. Recent formations.

Sample Nr	Depth	Macropetrographic analysis
31	88.00-89.00	Black lignite with plant remnants
32	89.00-90.00	Softer lignite black, with little presence of clastic matter
33	90.00-91.00	Black lignite with plant remnants A8
34	91.00-92.00	Black lignite with plant remnants thin itercalations of clastic matter and of bright organic matter
35	92.00-92.50	30 cm of argillaceous lignite black with thic seams of clastic matter. 20 cm of carbonaceous clay of deep gray color
36	92.50-92.70	Mixed phase of clastic matter and black argillaceous lignite
37	92.70-93.00	Mixed phase of argillaceous lignite dull hard of black color with xylite
38	93.00-94.00	Lignite of deep brown to black color homogeneous hard with few seams of clastic matter, A9
39	94.00-94.20	Lignite black with intercalations of brown color and successions of dull and bright organic matter
40	94.20-94.50	Marlaceous clay of deep gray color and occasionally presence of lignite
41	94.50-94.70	Lignite of black to brown color, homogeneous color A11
42	94.70-95.00	Marlaceous clay with few xylite of light color
43	95.00-96.00	Dull homogeneous black lignite
44	96.00-97.00	Black to brown lignite with few seams of clastic matter
45	97.00-98.00	70 cm of black to brown lignite with few seams of clastic matter. .30 cm of carbonaceous clay with gasteropods
46	98.00-99.00	Carbonaceous clay with gasteropods and plant remnants
47	99.00-99.20	Carbonaceous clay with gasteropods and plant remnants
48	99.20-100.00	Lignite of deep brown to black color with gasteropods relatively homogeneous
49	100.00-100.30	Marlaceous clay of deep gray color with large fossils and plant remnants
50	100.30-101.00	Black, dull soft, lignite occasionally enriched in ferrous oxide
51	101.00-101.30	Black, dull soft, lignite occasionally enriched in clastic matter
52	101.30-101.50	Marlaceous clay of deep gray color with large fossils and plant remnants and xylite A12
53	101.50-102.00	Black, dull soft, lignite occasionally enriched in clastic matter homogeneous
54	102.00-103.00	Black, dull hard, lignite occasionally enriched in clastic matter
55	103.00-104.00	Black, dull hard, lignite occasionally enriched in clastic matter
56	104.00-105.00	Black, dull hard, lignite occasionally enriched in clastic matter
57	105.00-106.00	Black, dull occasionally bright hard, lignite occasionally enriched in clastic matter A14
58	106.00-106.30	Carbonaceous clay of deep gray color with xylite hard and bright
59	106.30-107.00	Clay of color with fossils and plant remnants
60	107.00-107.20	Transition of hard carbonaceous clay to argilaceous lignite of black color hard relatively homogeneous A14
61	107.20-107.70	Hard dull carbonaceous clay with xylite and few fossils, severiously tectonised
62	107.70-108.40	Carbonaceous clay of light gray to green color with few plant remnants and xylite A15

Table 1. Macropetrographic analysis of the borehole B-240 from the depth of 74,50m to the depth of 108,40m

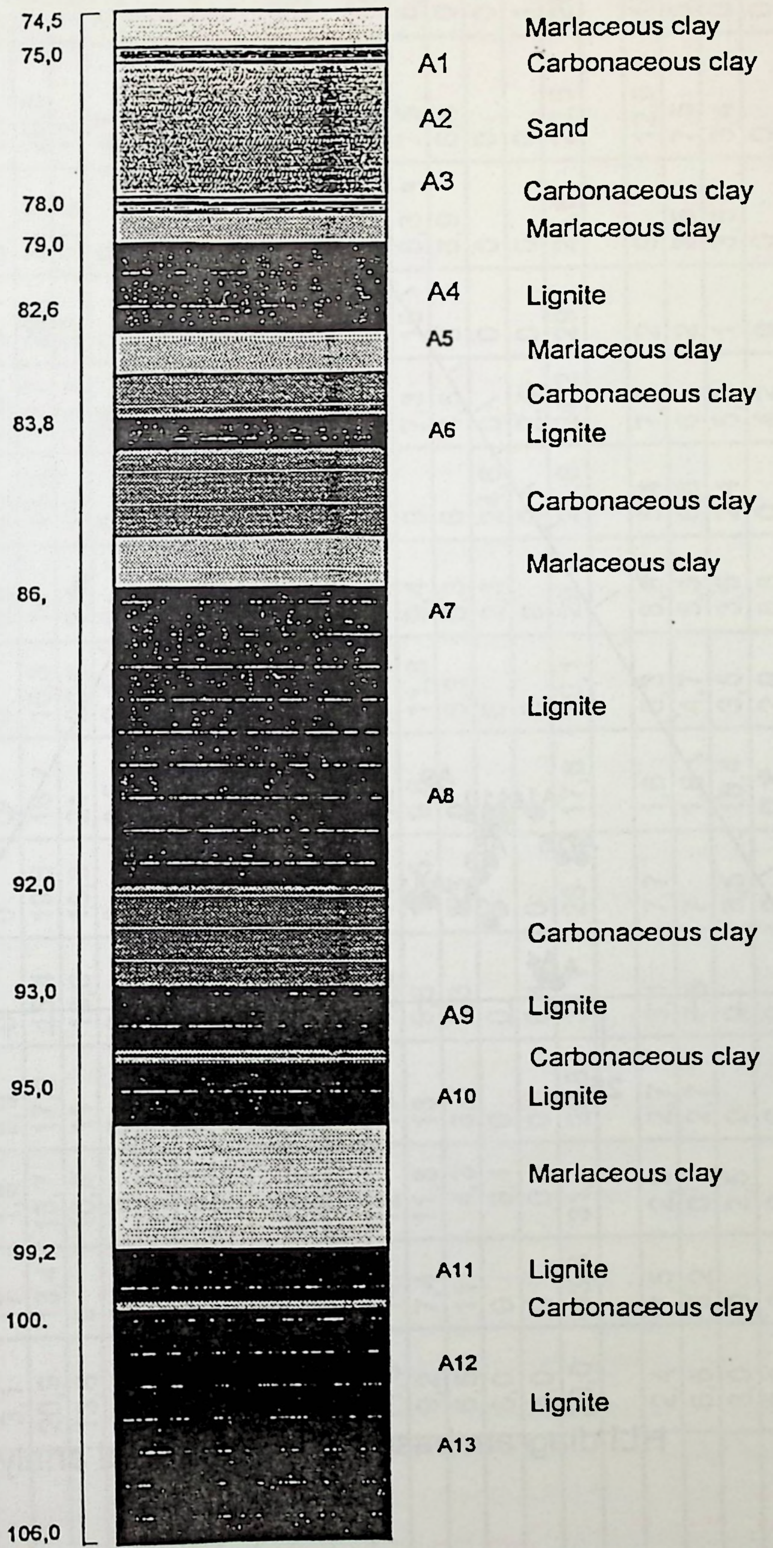


Figure 3. Detailed stromatographic section of the lignite deposit of "Apophysi"

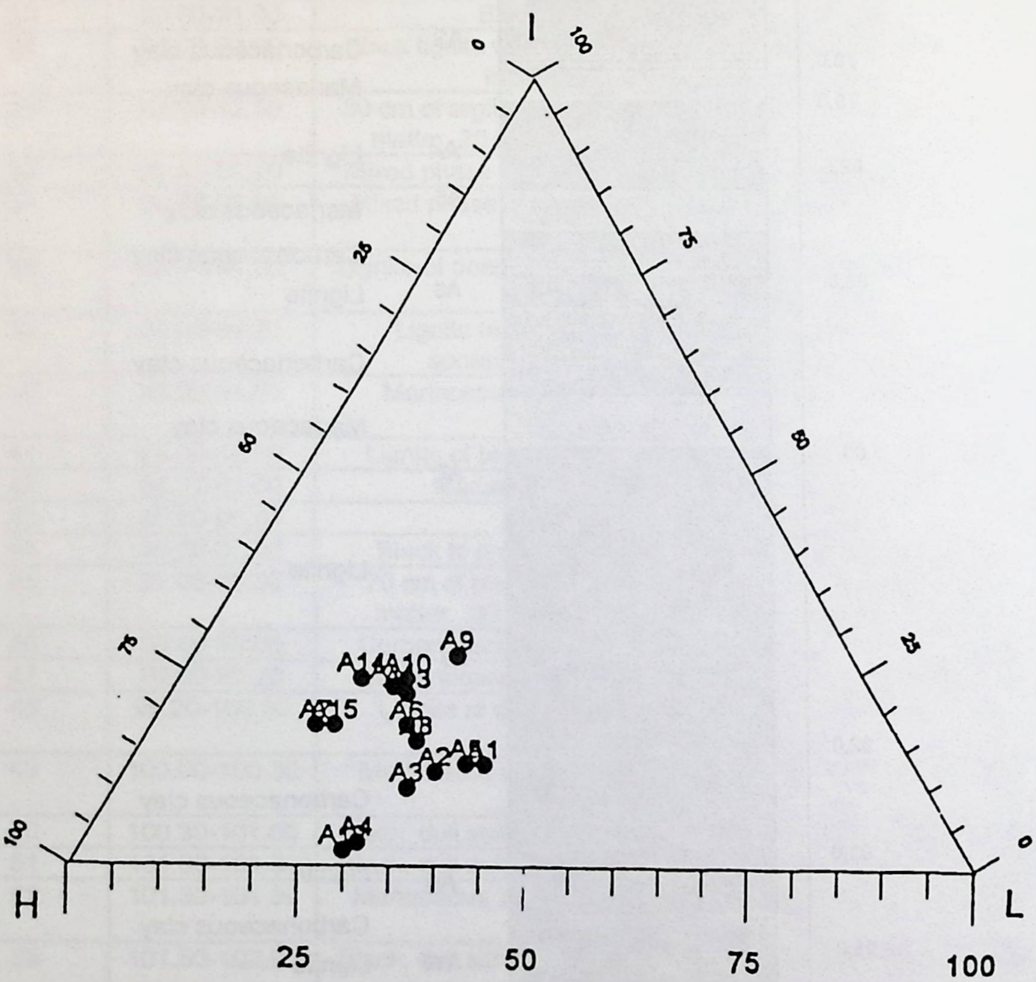


Figure 4. HLI diagram based on the maceral analysis

Maceral	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
Huminite															
Textinite	3,1	17	1,8	8,9	0	0	0	0	0,6	4,2	0,6	0	0,7	1,4	0
Texto-ulminite	20,9	13,4	13,7	17,2	15,4	19,6	16	15,3	14	13,2	12,7	29	21,5	20,5	29
Eu-ulminite	13,6	9	16,8	11	18,6	16,8	21	20,6	9,4	15	15,1	32	21,5	17	19
Attrinite	0	0	0	0	0	0	3,5	2,4	6	0	25	0	0	4,7	7,7
Densinite	4,9	0	11,2	16	0	5,6	15	4,1	14,1	0	12,1	0	4,2	5,4	0
Levigelinite	0	4,4	14.3	9	7,7	8,4	8,3	9,4	0	18	7,3	0	0	0	0
Porigelinite	0	5,2	0	0	0	0	0	0	0		0	0	0	0	0
Corpohuminite	5,5	6,7	0	5	8,3	3,5	0	1,8	0	10,2	2,4	8	5	6,8	0
Total	48,0	55,7	58,1	67,1	50,0	53,9	64	53,6	44,1	60,6	52,8	69	51,4	55,8	55,7
Liptinite															
Sporinite	11,3	14,5	12	10	12,8	14	12	7	12,3	9,6	9,7	12	10,4	6,2	16,6
Cutinite	9,2	7,4	11,8	13	9,6	10,5	9,6	11,8	9,4	9	7,3	15	8,3	7,5	8,8
Resinite	6,5	11	4,3	3,4	8,3	3,5	0	5,3	5,3	6	4,8	0	6,9	6,8	0
Liptodentrinite	6,0	0	3,1	0	0	0	0	6	2,3	24,6	0	0	0	0	0
Suberinite	6,0	0	0	0	6,4	0	0	0	0	0	2,4	0	0	0	1,1
Total	39,0	33,6	31,4	29,8	37,1	28	17,8	30,1	29	24,6	24,2	29	25,6	20,5	26,5
Inertinite															
Fusinite	2,4	7,5	2,5	2,7	5,1	7,7	1,6	5,3	8,8	5,4	7,3	2	9	12,9	14,4
Semifusinite	6,8	5,2	0	2,7	7,6	7	1,6	4,7	5,3	6,6	6	2	3,5	7,5	3,3
Sclerotinite	3,0	0	2,5	0	0	3,5	10,4	3,5	3,5	2,4	5,5	1	3,5	3,4	0
Inertodentrinite	0,0	0	0	0	0	0	0	2,9	8,8	0	4,2	0	0	0	0
Total	12,2	12,7	5	5,4	12,7	18,2	13,6	16,4	26,4	14,4	23	5	22,8	23,8	17,7

Table 2. Maceral analysis data

It consists of an alluvial mantle that consists of erosion products and other older formations, as well as recent terrestrial silts and soil concentrations round the margins of the basin.

Detailed data on the geology of the area are included in the paper of Koukouzas et al., 1976, "Coal exploration of Anargiri area, Aminteon (W. Macedonia)"

Macroscopic analysis of the samples

The major objective of the present paper is the macro-microscopic analysis of the samples. The macroscopical analysis includes the identification and the recording of the various geological formations that were drilled in the B-240 borehole paying special attention to this part of the borehole that comprises the lignite beds. Based on the bulk description of the borehole it seams that the formations close to the surface are alternations of clay, sand and all the intermediate categories. In ceratin parts the presence of marls formations is particularly apparent. Marl appears at 45,00m and it is followed by argillaceous sediments. The formation of marl seams to play the role of the hanging layer of the lignite beds. The depth were this formation appears is at 80,00m. The succession of the beds seams to be a continuous unity that occasionally was dirupted by regional geological phenomena. The succession of the lignite ends at 108,00m and consists of alternate beds of lignite, marl and clay enriched in organic matter. Under the lignite beds the major formations are clay and sand till the 153,00m where the borehole stopped.

Specifically the part of the borehole where the lignite beds prevail (Table 1, Fig. 2) seems to be continuous disrupted occasionally by thin beds of clastic matter. The thickness of the beds rich in clastic matter can reach the 0,50 cm. The most important disruption appears at the depth of 99,00 m and its thickness is 1,20m.

The lignite appears compact rich in xylite and plant remnants. Generally speaking fossils are not abundant and where they appear they are connected with beds with little hardness. At 101,00 m the lignite appears enriched in iron oxide as a result of a possible impregnation or a geochemical procedure that has already begun the successive fragmentation of the organic matter resulting in the increasing of the calorific value of the samples. The fossils that appear are mainly gasteropods. The general picture of the deposit is of a continuous horizon with restricted changes of the depositional environment (Fig 3).

For the first 3 m of the borehole the lignite appears as alternative beds with clay and marl after this succession 60cm of pure marl follows, and then 2m of lignite compact, black and homogeneous. For 5,00m follow alternative beds of lignite and clastic matter that is represented by clay and marl. At 86,50 m appears soft lignite that is succeeded by hard lignite rich in plant remnants and xylite. The thickness of this horizon is around 5,5m and is followed by alternations of clastic matter and lignite till the 98,00 m where the succession drifts to clastic mainly marlaceous clay for 1,20 m. It is followed by a bed of soft lignite enriched in fossils and xylite till the 106,00 m where the carbonaceous clay prevails and gradually drifts to marlaceous clay at 107,70 m where the lignite seam seems to end.

Microscopic analysis

The microscopic analysis consists of the maceral analysis of the samples and the determination of the rank (Table 2, Fig. 7).

For the determination of the rank 100 points on each sample were measured. The measurements were taken on Eu-ulminite. The maceral analysis is carried out as follows:

On each sample 500 points were measured taking the liptinite group and the inorganic matter. After that another 500 points under fluorescense were measured on the liptinitic group and on the inorganic matter according Diesel, 1992.

According the petrographic data and their representation on the HLI diagram (Fig 4) the strong presence of the liptinite group is apparent. It seams that the presence of the liptinite is connected to the presence of the inorganic matter (A1,2). The samples with high values of liptinite are generally soft lignites rich in inorganic matter, whereas the hard lignite rich in xylite is enriched in huminite and inertinite. The presence of high percentages of liptinite and xylite denotes vegetation of higher plants. The higher value of inertinite is connected to a sample of lignite particularly hard and rich in xylite.

The presence of levigelinite give a gelification stage where the procedure of fragmentation of the organic matter has already begun. The presence of inertinite denotes that the environmental conditions that prevail where midly oxic, this is connected to the presence of inorganic matter. The percentages of suberinite, corpohuminite and resinite are also connected to higher plants vegetation and support the already mentioned aspect of the vegetation type.

Whereas on the top of the borehole it seams that the prevailing conditions are anoxic with the presence of levigelinite (A2,3,4,5), on the basis the presence of inertinite (A13,14) is strong denoting oxic environmental conditions.

The reflection data of the samples is a basic factor to estimate the calorific value of the lignite beds (Table 3, Fig 5). The results of the analysis estimate a intermediate stage of rank between peat and lignite. The reflectance of the sample is from 0,22-0,29% measured on the Eu-ulminite.The fluctuation of the results are apparent and it seams it is connected with the presence of inorganic matter. In general the soft lignite samples give lower reflectance measurements compared to the measurements taken on hard lignite samples rich in xylite. The diagram that presents the reflectance data plotted against the depth shows a picture that denotes that in low stages of rank the depth as parameter coalification plays an unimportant role because the time of deposition is so sort that the procedures of coalification did not have the time to give important results of their activities.

The higher values of reflectance give sample A10 that according the macropetrographic description it has to do with a hard deep brown lignite rich in xylite. The lowest value gave the samples that originate from horizons rich in clastic matter and show low compunction (A1,2,7).

Table 3. Reflectance and calorific value data

Sample Nr	Depth	Reflection	Calor. Val.
A2	76,5	0,235	
A3	78	0,27	
A4	80,5	0,29	4372
A5	82	0,24	4043
A6	83,5	0,23	4317
A7	86,7	0,24	4024
A8	90	0,28	4643
A9	94	0,28	4990
A10	97	0,29	4742
A11	100	0,25	3788
A12	102	0,25	4422
A13	105	0,27	4392
A14	107,2	0,29	4968
A15	108,4	0,24	2788

Fig. 5. Reflectance against depth plot.

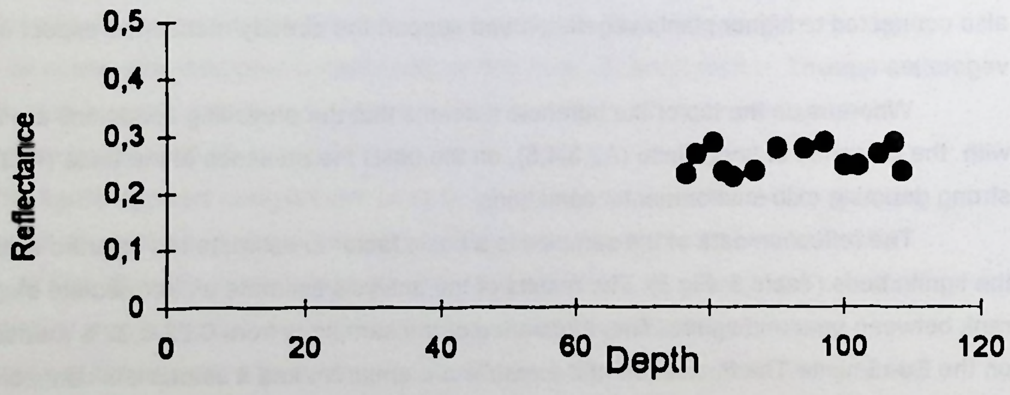
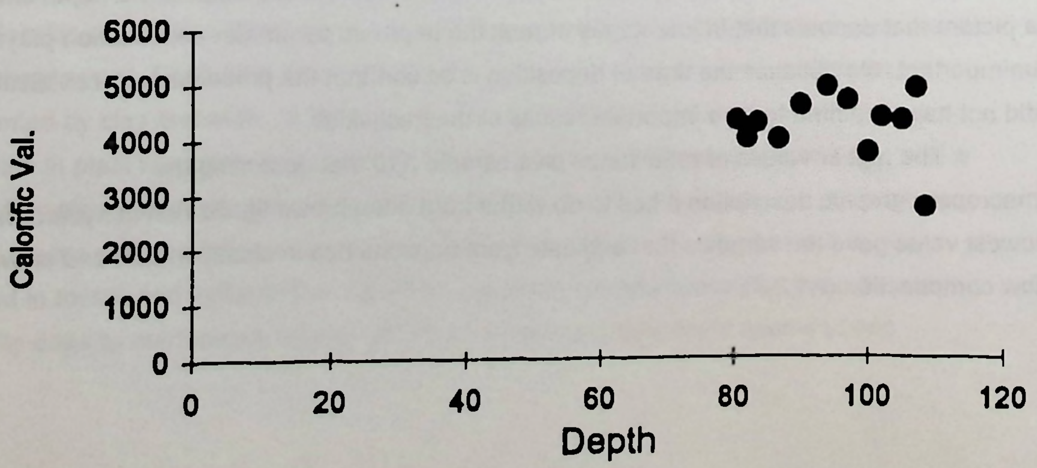


Fig. 6.Calorific value against depth plot



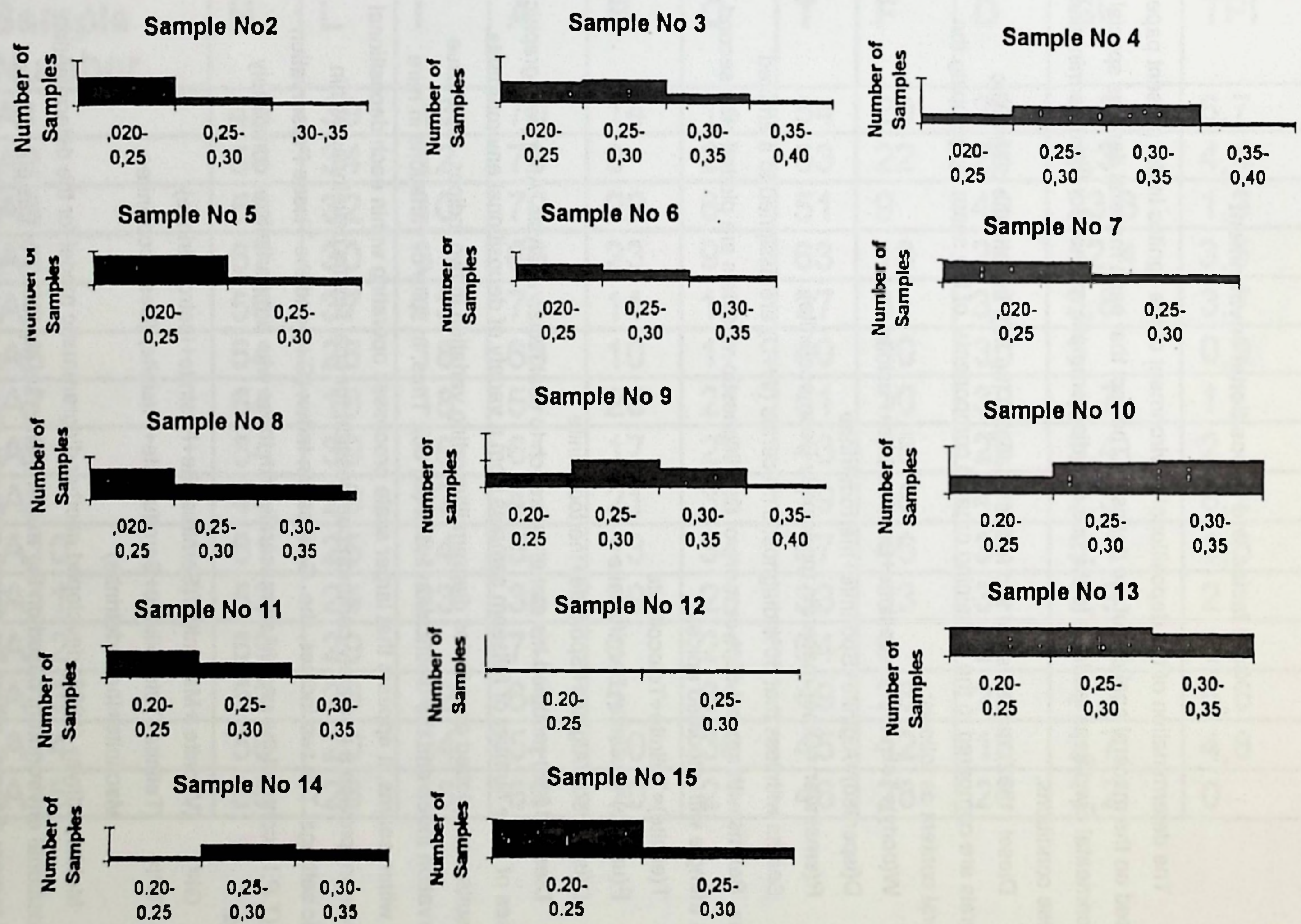


Figure 7. Reflectance data histograms based on the reflectance analysis of each sample

Data on the calorific value of the samples kindly offered by I.C.P. show exactly the same trend with the reflectance data (Table 3, Fig.6). The higher values are given from compact samples. It is apparent the correlation between the higher and lower values of the reflectance and the calorific value.

Coal facies and depositional environment

The determination of the depositional environment of the lignites in the present paper is based on the maceral analysis of the deposits. The fact that each maceral denotes special environmental conditions leads us to the use of a diagrammatic method for the determination of these conditions.

Diesel (1982) made use of two facies triangles (fig 8a). Initially the diagnostic macerals are compared to the remaining organic components, of the seam by grouping the maceral content as follows:

W(oody)=Telinite+Telocollinite+Semifusinite+Fusinite

D(ispersed)=Alginite+Sporinite+Inertodetrinite

R(emainder)=Other macerals (principally Desmocollinite)

Seams with less that 50% diagnostic macerals (W+D) are assigned to a «mixed facies». Seams with around 50% or more of the diagnostic macerals are plotted on a second facies triangle with modified apices:

T(elinite)=Telinite+Telocollinite

F(usinite)=Fusinite+Semifusinite

D(ispersed)=Alginite+Sporinite+Inertodetrinite

Diesel (1986) modified his earlier approach to coal facies analysis. After petrographic analyses of large number of fullseam samples from a variety of depositional environments, the results were plotted on a facies diagram illustrating variation in two indices, the Tissue Preservation Index and the Gelification Index (fig 8c). Thus, in spite of variations in mire facies within seams, it appears that larger scale processes operating within each depositional environment provide a relatively common composition for coal seams developed within specific settings. The two indices, the Gelification Index (G.I.) and the Tissue Preservation Index (T.P.I.) contrast the ungelified macerals with those who are partially or completely gelified.

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

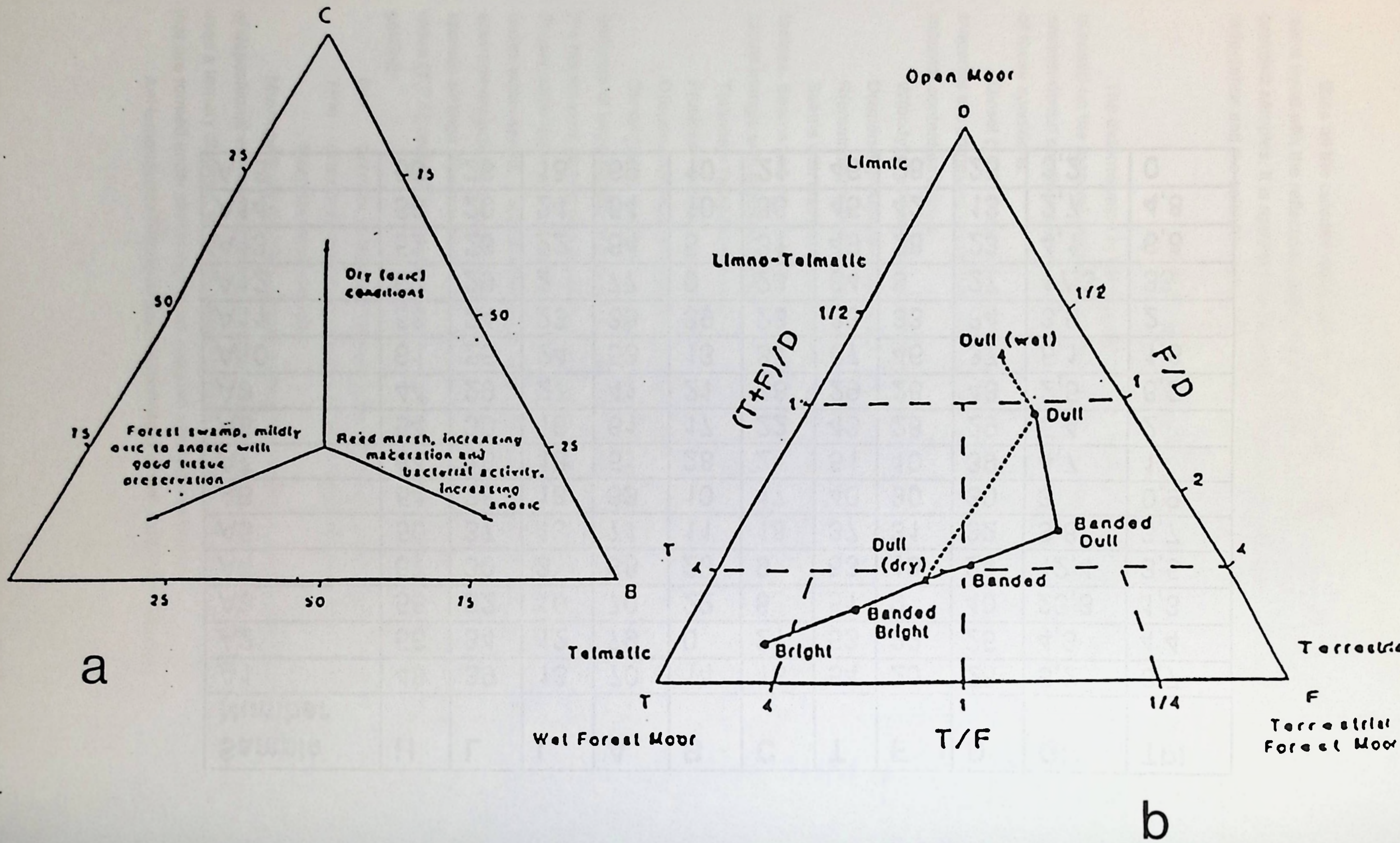
TPI= (Telinite+Telocollinite+Semifusinite+Fusinite)/(Desmocollinite+ Macrinite+Inertodetrinite)

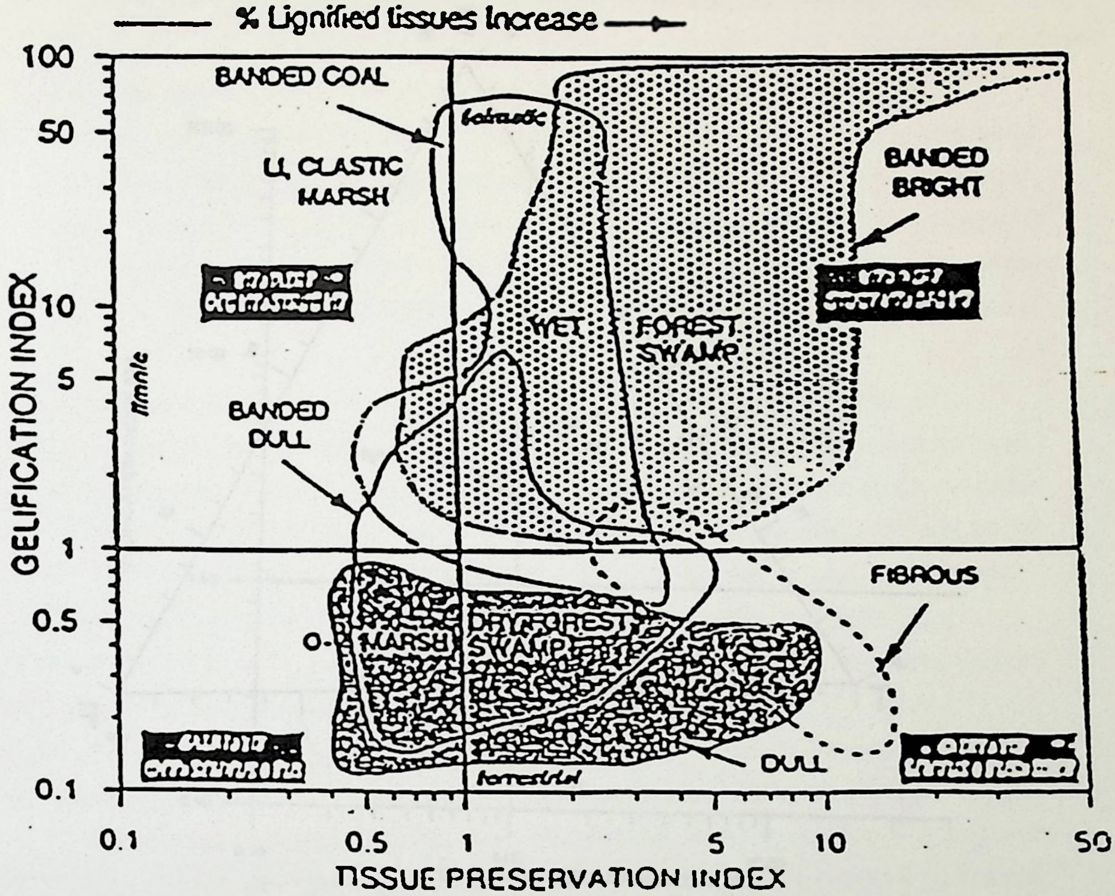
Mukhopadhyay (1986) developed another diagrammatic model for the determination of depositional environment based on the maceral analysis (fig. 8b). For this purpose he used a ternary diagram, where the apices represent different combinations of maceral types that are formed under similar conditions. Diagram apices are defined as:

A=Humotelinite+Terrestrial Exinite(Sporinite+Cutinite+Suberinite)+Resinite

Sample Number	H	L	I	A	B	C	T	F	D	GI	TPI
A1	48	39	13	70	14	16	54	20	26	5,2	6,7
A2	56	34	12	79	0	21	53	22	25	4,3	4,4
A3	58	32	10	70	22	8	51	9	40	23,3	1,3
A4	67	30	3	68	23	9	63	13	24	12,4	3,5
A5	50	37	13	71	11	18	37	31	32	3,8	3,7
A6	54	28	18	63	10	17	40	30	30	3	0,9
A7	64	18	18	51	28	21	51	10	39	4,7	1
A8	54	30	16	61	17	22	43	28	29	5,4	2
A9	44	29	27	41	21	38	29	28	43	2,5	8,2
A10	61	25	24	53	13	34	67	46	37	5,1	1,6
A11	53	24	23	38	39	23	33	33	34	3,9	2
A12	69	29	2	77	0	23	64	9	27	17,3	33
A13	52	26	22	64	5	31	49	28	23	4,1	6,8
A14	56	20	24	54	10	36	45	42	13	2,7	4,8
A15	56	26	18	69	10	21	46	28	26	3,2	0

Table 4. Distribution of the maceral ratios and percentages as plotted in figures 3, 8 a,b,c

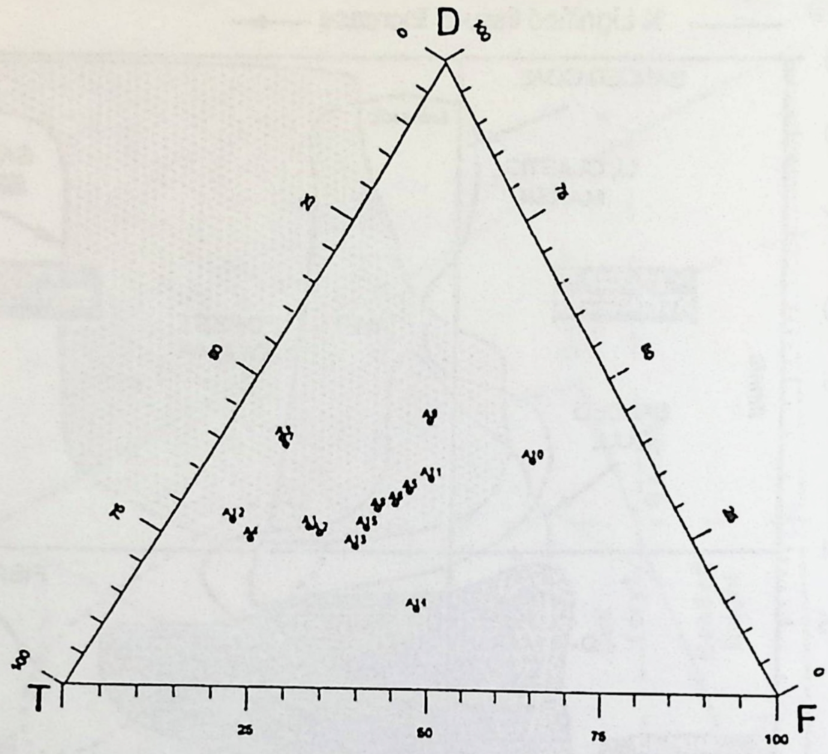

C
B
25
50
75
Dry (oxic) conditions
Forest swamp, mildly oxic to anoxic with good tissue preservation
Reed marsh, increasing maceration and bacterial activity, increasing anoxic
a
Open Moor
O
Limnic
Limno-Telmatic
(T+F)/D
F/D
1/2
1
2
4
Dull (wet)
Dull
Banded Dull
Dull (dry)
Banded
Banded Bright
Bright
Telmatic
Terrestrial
T
F
1/4
T/F
Wet Forest Moor
Terrestrial Forest Moor
b



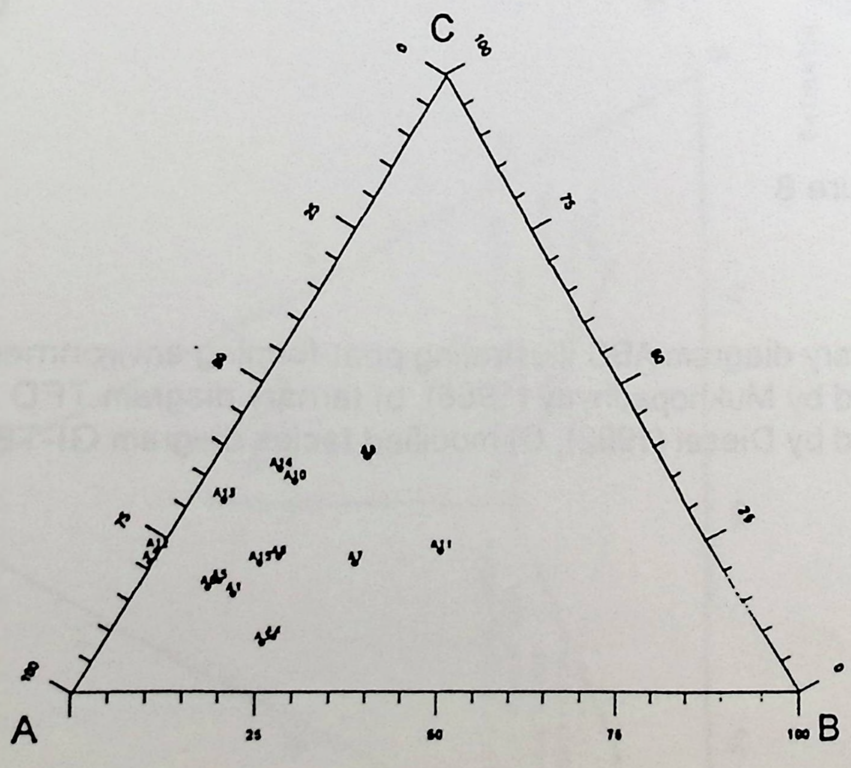
C

Figure 8.

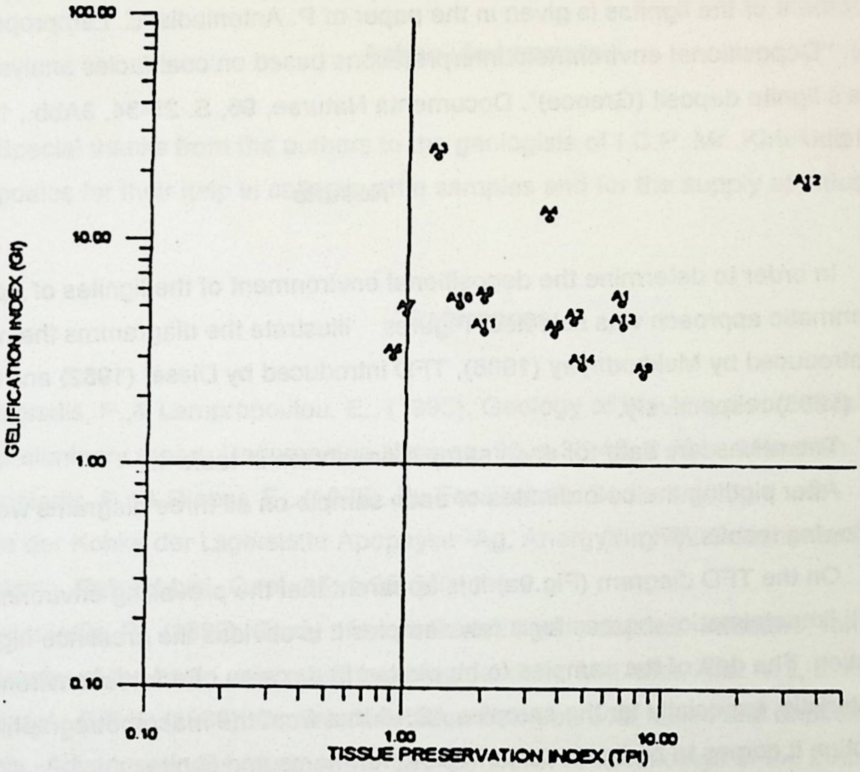
a) Ternary diagram ABC illustrating peat-forming environments modified by Mukhopadhyay (1986), b) ternary diagram TFD modified by Diesel (1982), C) modified facies diagram GI-TPI from Diesel



a.



b



C

Figure 9.

Determination of the depositional environment of Apophysi lignite deposit using : a) Ternary diagram ABC modified by Mukhopadhyay (1986), b) ternary diagram TFD modified by Diesel (1982), c) modified facies diagram GI-TPI from Diesel

B=Humodetrinite+Liptodetrinite+Mixinite+Sapropelinite+Alginite
C=Inetrinite

Further information on the diagrammatic interpretation of the depositional environment of the lignites is given in the paper of P. Antoniadis, E. Lampropoulou (1995). "Depositional environment interpretations based on coal facies analysis of Drama's lignite deposit (Greece)". Documenta Naturae, 96, S. 25-34, 3Abb., 1Tab., München.

Results

In order to determine the depositional environment of the lignites of Apofysi the diagarmmatic approach was selected. Figures illustrate the diagramms that were used ABC introduced by Mukhodhyay (1986), TFD introduced by Diesel (1982) and GI-TPI by Diesel (1986) respectively.

The necessary data for each sample are shown in table 4.

After plotting the co-ordinates of each sample on all three diagrams we end up on the following results. (Fig. 7)

On the TFD diagram (Fig.9a) it is apparent that the prevailing environment is limnic ti limnotelmatic whereas for a few samples it is obvious the presence higher plants vegetation. The drift of the samples to be plotted in the area of a forest environment is characteristic, especially for the samples A8,10 that from the macropetrographic description it comes to be lignites rich in plant remnants and lignite.

On the ABC diagram (Fig 9b) most of the samples are plotted in the area of a limnic to telmatic forest. The different trends of the samples close to bottom and the top respectively are also here apparent. Especially these trends are represented with the differentation of the environmental conditions between bottom and top oxic and anoxic respectively.

Closing the GI-TPI diagram (Fig 9c) gives a limnic to telmatic forest environment with marginal cases A3 plotted in the telmatic environment and A9,14 plotted in the area of the limnic with moderate oxic conditions.

As a result we can assume that the lignite deposit of Apofysi is a product of higher plants vegetation that starting with wre deposited in a limnic environment that moderate oxic conditions prevail. This environment drifted to telmatic with anoxic conditions and preservation of the plant tissues.

Conclusions

The lignite deposit of Apofysi is a product of higher plant according the maceral analysis data correlated to the depositional analysis data. The rank of this deposit is of intermediate stage between peat and lignite with reflectance values 0,22-0,29% on Eu-ulminite. The conditions of the depositional environment were middly oxic to anoxic and the type was starting with limnic that drifted to telmatic.

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