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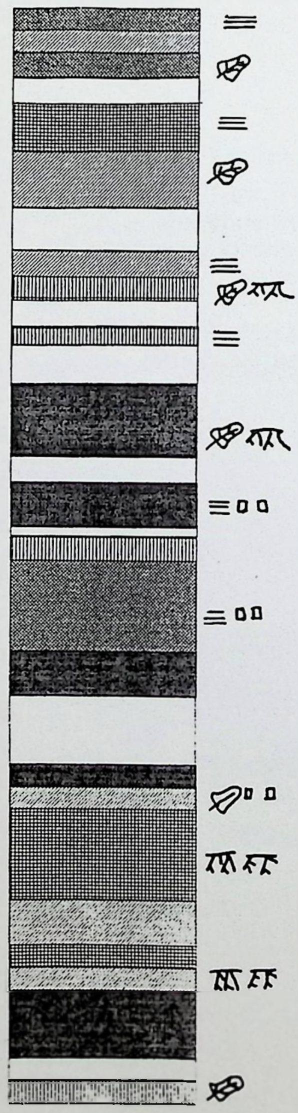
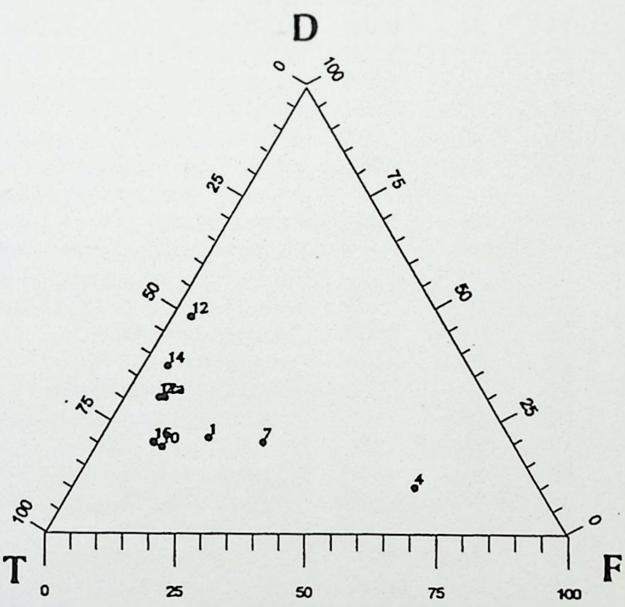
No. 96





GREEK BROWNCOALS

Geology -- Petrography

DOCUMENTA NATURAE

Nr. 96 1995

ISSN 0732-8428

Herausgeber:
Dr. Hans-Joachim Gregor, Palsweiserstr. 5m, D-82140 Olching
Dr. Heinz J. Unger, Nußbaumstraße 13, D-85435 Altenerding

Die Zeitschriftenreihe erscheint in zwangloser Folge mit Themen aus den Gebieten Geologie, Paläontologie, Botanik, Anthropologie, Domestikationsforschung, Vor- und Frühgeschichte, Stratigraphie, Lagerstättenkunde usw.

Die Zeitschriftenreihe ist auch Mitteilungsorgan der Paläobotanisch-Biostratigraphischen Arbeitsgruppe (PBA).

Für die einzelnen Beiträge zeichnen die Autoren verantwortlich, für die Gesamtgestaltung die Herausgeber.

Überweisung des Heftpreises erbeten auf das Konto 1548460 bei der Sparkasse FFB (BLZ 700 530 70) - Inh. H.-J. Gregor.

Bestellungen bei Buchhandlungen und den Herausgebern.

Umschlagbild: H.-J. Gregor und Autoren.

Content **Seite**

ANTONIADIS,P. & LAMPROPOULOU, E.: Depositional Environment Interpretations based on Coal Facies Analysis of Lava`s Lignite Deposit (Greece)..1-12

\- - - - - : Depositional Environment Interpretations based on Coal Facies Analysis of Chomatero-Koroni`s Lignite Deposit (Greece)..13-24

\- - - - - : Depositional Environment Interpretations based on Coal Facies Analysis of Drama`s Lignite Deposit (Greece)..25-34

\- - - - - : Geology of the Amynteon Main Lignite Deposit - a preliminary report..................................35-43

In eigener Sache - Nachwort - Reklame..44-48
Der Herausgeber H.-J.Gregor

DOCUMENTA NATURAE, 96 , S.1-12, 3 Abb., 1 Tab., München 1995

DEPOSITIONAL ENVIRONMENT INTERPRETATIONS BASED ON COAL FACIES ANALYSIS OF LAVA'S LIGNITE DEPOSIT (GREECE)

P. Antoniadis[1], E. Lampropoulou[1]

Key Words: Lava, Lignite, Coal Facies Diagramms, Depositional Environment, Physicochemical Conditions, Preservation of Plant Tissues, Telmatic to Limnic, Telmatic to Fluviatil Environment

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ZUSAMMENFASSUNG

Die vorliegende Arbeit bezieht sich auf die paläogeographischen Verhältnisse der Braunkohle-Flöze des Beckens von Lava, das wiederum im geologischen Rahmen zum grossen Beckenzug gehört, der sich von den Nordgrenzen Griechenlands bis Nord-Thessalien erstreckt. Hierzu wird zunaechst einmal allein an Hand von kohlepetrographischen Daten und auf den Arbeiten von Diesel (1982, 1986) und Mukhopadhyay (1986) basierend, auf die paläogeographischen Verhaeltnisse im Untersuchungsgebiet geschlossen. Dieses Gebiet zeichnet sich dadurch aus,daß der Versuch zu einer paläogeographischen Rekonstruktion bereits durch anderen Methoden vorgenommen wurde, und dadurch ein Vergleich der Ergebnisse ermöglicht wird. Zu diesem Zweck wurden die Ergebnisse aus 11 Proben einer repräsentativen Bohrung untersucht. Zusammenfassend für das Arbeitsgebiet kann man auf ein wechselndes Milieu von terrestrisch-fluviatil zu limno-telmatisch schließen. Mit vorherrschend terrestrischem Einfluß zu Beginn (unteres Flöz) ändert sich das Milieu zunächst zu rein limnischen (Mergel- und Tonzwischenlage) und weiterhin zu limno-telmatischen Bedingungen bis zu solchen offener Gewässer (Oberes Flöz).

ABSTRACT

This paper studies the characteristics and the depositional environment of Lava's lignite deposit. For this purpose the data from the petrographic analysis of 11 samples from a borehole drilled in a quarry in the region of Lava were incorporated in the present study. Previous works in the area (geological and petrographical) determine 3 lignite beds fully developed, characterising the second and the third as one and one more on the top, which is lithologically xylite and it is locally developed (SE region). The present paper is an effort to determine the depositional environment of the lignite deposits according the diagrammatic methods of Diesel (1982,1984) and Mukhopadhyay (1986). Simultaneously the results are compared to the classical methods (palaeobotany and palynology) that are commonly used. The depositional environment for Lava's lignite beds is varied, which is a proof of the geological evolution of the area. Based on the rank determination the lignite is classified on the group of soft brown coals or on the transition stage of peat to lignite. Generally speaking the depositional environment is telmatic to limnic for the lignite and for the xylite telmatic to fluvial with large terrestrial impact. The differences in the composition of the lignites are due to the vegetation and depositional environment.

INTRODUCTION

Lava's basin is situated 40Km SE of Kozani and around 100Km NW of Larisa. It is surrounded by the mountain chain of Marathousa to the North , Tsoukas to the East, Flambouro to the South and Boursagas to the West. The lignite deposits in the area are known for 50 years and the exploitation was initially started by small private mines and it is continued by Larko inc. In detail the researchers that worked in the area were, Karageorgiou (1951), Anastopoulos & Brousoulis (1973), Anastopoulos

Kaouras(1994). The calorific value of the deposits is 2400Kcal/Kgr, the tar content is about 10-20% and the moisture content is 48%-56%. Vitrinite reflectance is 0,34-0,36% and the C content 62-64%. All these characteristics lead us to classify these lignite deposits to the category of soft brown coals. According to the paleobotonical and the micropalaeontological studies of the samples which are in the paper of Antoniadis et al. (1994) included, the age of the deposits is Up. Miocene. In the area from time to time various research boreholes were carried out by the Insitute of Geology and Mineral Exploration (I.G.M.E.) and by Larko inc. The present study is based on the data of the samples from a representative borehole, and its goal is to determine the characteristics and the depositional environment of these lignite deposits.

GEOLOGY

The deposit of the Lava basin after Aubouin (1957) is a part of the Pelagoniki zone. The formation of the rocks in the area starts from Palaeozoic and lasts till Quartenary. The oldest are crystalline rocks of the Palaeozoic and they are succeeded by Permian and Triassic metamorphic sediments followed by the marbles of Triassic and Jurassic Anastopoulos & Koukouzas(1972). On the top of the profile appear cherts and calcites with intercalations of Up. Jurassic ophiolites. Cretacean and L. Quaternary are missing in the area. According Bruhl (1968) Anastopoulos et al. (1972)and Pavlidis (1985) series of movements took place as a result of intense tectonism during M. Miocene till Up. Miocene, when the Hellenides were formed. The same period took place the formation of the Vevi-Serbia basin and the major lignite deposits of the area, that are divided into 3 parts: A. Florina's B. Ptolemaidas and C. Serbia. These deposits comprise usually several smaller ones. The most recent rocks in the area consist of fluvial, deltaic and limnic sediments.

The base of the lignites consists of coarse, sand deposits and conglomerates in alternation with marls, clays, siliceous clays and finely granular sand. These succession compose Neogene 1 in Fig. 1a,b. In the higher part of the base of the lignite deposit appear veins that denote the start of peat formation. This seam is enriched with fossils and plant relicts and it consists of alternations of finely grained sand, clays and siliceous clays.

The sediments on the top on the deposit consist of 26m of alterations of finely grained sand, clays and siliceous clay. This succession corresponds to Neogene 2 of Fig 1a,b

The lignite deposit starts with 60-70cm transitions of siliceous clay and finely grained sand, then follows a 7m lignite seam. A grey colour seam of marl interrupts the lignite seam with 2,20-2,60 thickness. In the perimeter of the basin gradually appears a seam of xylite that was detected on the boreholes and does not appear in the exploitation area. The Neogene deposits start with a succession of transitions of marlaceous limestones and sandstones with 100m thickness rich in fossils and plant relicts. The higher part of the profile is occupied by quaternary formations of 10m thickness that consist of coarse sand.

PETROGRAPHIC STUDY OF THE LIGNITE DEPOSIT.

According to the lithotype analysis of the deposit at a depth of 35 to 50m, it appears rich in xylite. The classification system used is that, that was introduced by

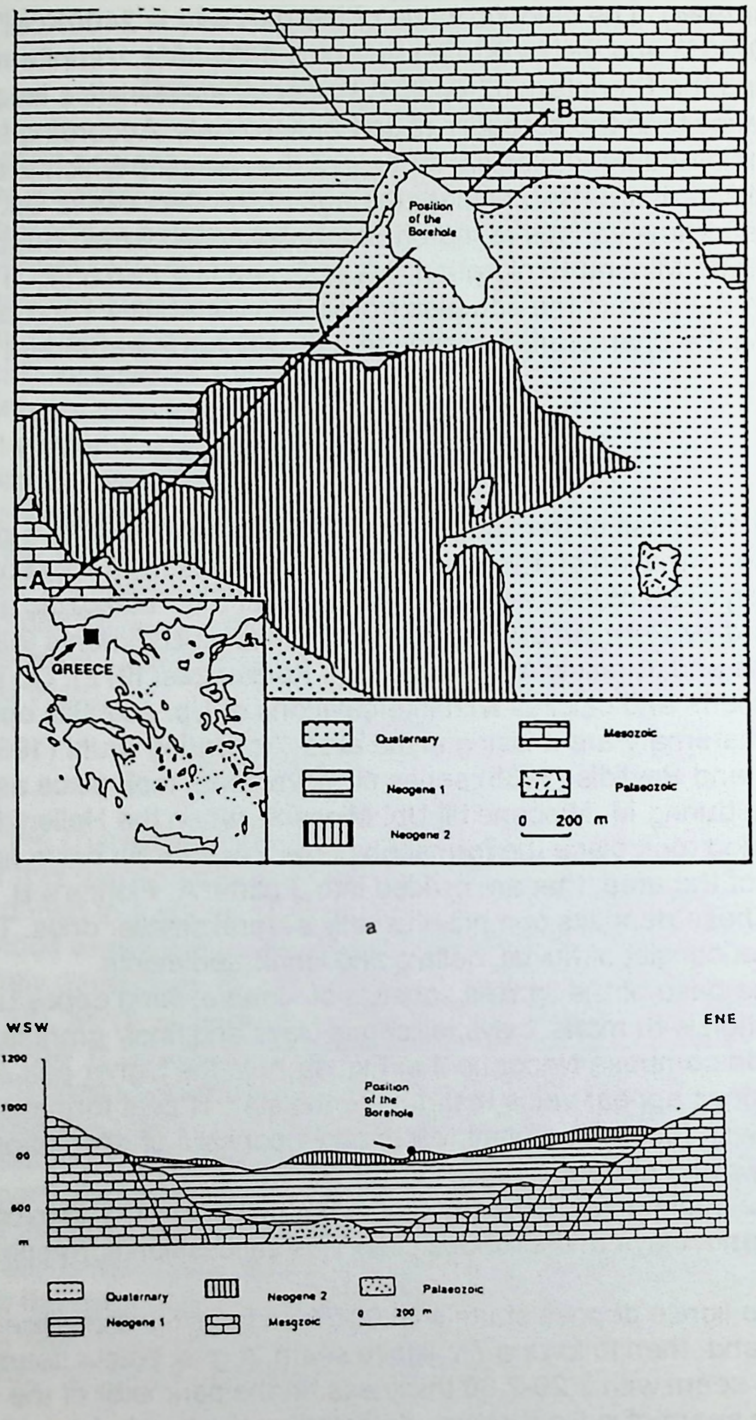
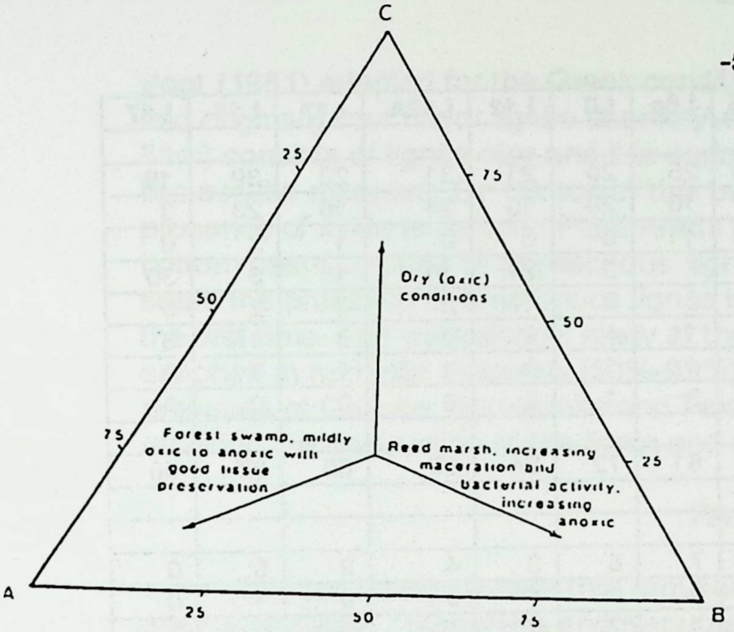
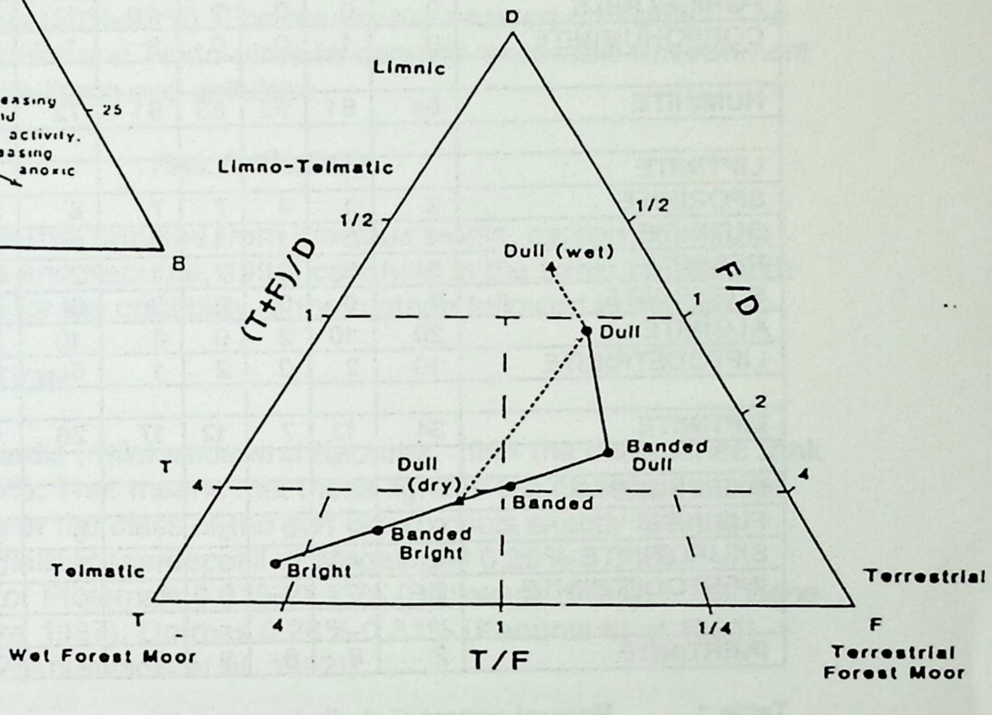


Figure 1. a) Geological map of the Lava basin Showing the osition of the borehole, b) Geological section with direction WSW-ESE in the lignite basin of Lava.





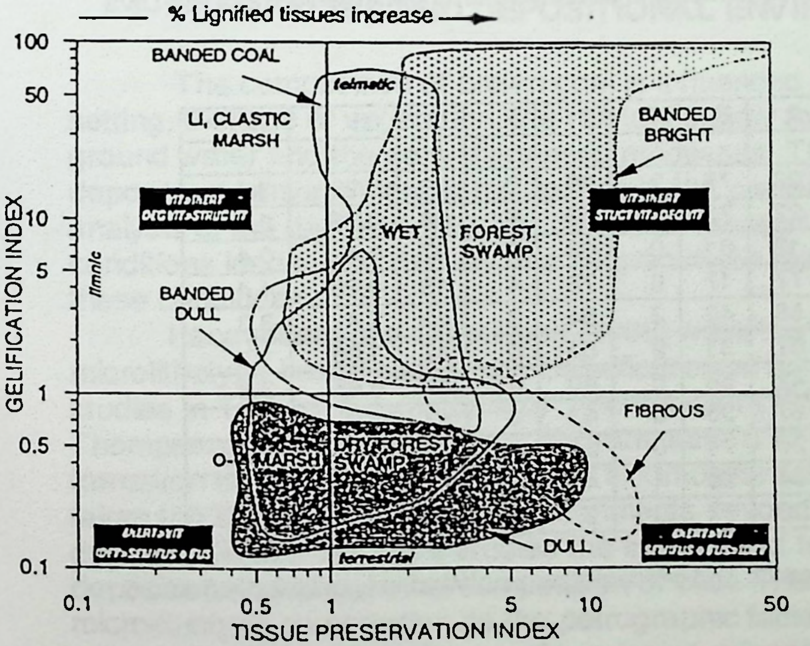


Figure 2: a) Ternary diagram ABC illustrating suggested peat-forming environments, modified from Mukhopadhyay (1986)
b) Ternary diagram TFD modified from Diesel (1982)
c) Modified facies diagram GI-TPI from Diesel

MACERAL	L1a	L2	L4	L5	L6a	L8	L12	L12A	L13	L15	L17
HUMINITE											
TEXTINITE	10	6	3	20	25	20	21	31	23	39	18
TEXTO-ULMINITE	7	20	3	37	10	29	10	24	16	23	3
EU-ULMINITE	2	1	9	15	11	0	0	0	1	2	0
ATTRINITE	36	11	51	0	7	3	24	10	15	3	30
DENSINITE	6	31	27	12	6	3	17	2	8	2	0
LEVIGELINITE	3	12	8	3	11	4	9	0	3	1	0
PORIGELINITE	0	0	0	2	4	1	0	1	1	1	0
CORPOHUMINITE	0	1	0	0	3	1	3	0	0	0	0
HUMINITE	64	81	93	83	81	72	84	68	66	67	56
LIPTINITE											
SPORINITE	3	1	4	7	7	8	3	4	2	5	0
CUTINITE	1	0	1	1	0	0	4	0	0	1	0
RESINITE	0	0	0	2	1	2	0	1	0	0	0
SUBERINITE	0	0	0	0	0	0	0	0	0	0	0
ALGINITE	20	10	2	0	8	10	3	11	18	25	26
LIPTODETRINITE	10	2	0	2	1	6	5	16	14	5	13
LIPTINITE	34	13	7	12	17	26	15	32	34	31	44
INERTINITE											
FUSINITE	0	2	0	3	1	0	0	0	0	0	0
SKLIROTINITE	0	4	0	3	1	2	0	0	0	1	0
INERTODETRINITE	2	0	0	0	0	0	0	0	0	0	0
INERTINITE	2	6	0	6	2	2	0	0	0	1	0

Table 1. Maceral content of studied samples in percent volume from the lignite of the Lava Basin.

Sample Nr	A	B	C	T	F	D	GI	TPI
L1a	23	75	2	20	0	80	0.29	3.8
L2	22	73	5	58	6	36	0.77	2.5
L4	19	81	0	63	0	37	0.4	0.4
L5	77	17	6	78	4	18	0.65	4.4
L6a	58	40	2	54	3	43	2.4	3.3
L8	67	31	2	53	0	47	1.05	10
L12	42	58	0	40	0	60	0.65	3.8
L12a	67	33	0	43	0	57	0.9	25
L13	29	71	0	33	0	67	0.7	1.03
L15	64	35	1	45	0	55	1.39	0.3
L17	23	77	0	9	0	91	0.69	21

Table 2. Disrtibution of maceral ratios and percentages as plotted in figures 2,3,4,5 and 6.

Vogt (1981) adapted for the Greek conditions (Kaouras, 1989). The deposit is divided into originally four major lignite seams (Antoniadis et al. 1994). The lower seam (48.1-51m) consists of lignite clay and it is enriched in plant relicts. At the top of this seam lies a xylite measure. On the top of this bed, appears a seam (45.4-48.2m) where the presence of xylite is definite. Plant relicts appear allover the profile. The third from the bottom seam consists of argillaceous lignite and carbonaceous clay. In the higher seam the presence of amorphous lignite is definite along with fusite that appears for the first time. The microscopic study of the 11 samples of the deposit showed that it is enriched in huminite macerals (50%-93%). The results are showed on Table1. The presence of Gelinite, Eu-ulminite and Texto-ulminite denotes anaerobic environment resulting the destruction of the lignin and cellulose.

PALYNOLOGY

The palynological data that aroused from previous works, carried out in the area (Antoniadis , Blickwede and Kaouras, 1994) conclude in the same results with the present paper and stand for the credibility of the method followed in this work.

RANK DETERMINATION

In the paper of Antoniadis , Blickwede and Kaouras, 1994 the determined rank of the deposits was 0.2-0.25%. That means that these lignites are classified on the borderline of peat and lignite or the class of the soft brown coals exactly like the majority of Greek deposits(Pleistocene deposit of Megalopoli 0.26%-0.31%, (Schonherr 1987), Pliocene of Ptolemais 0.31%-0.33% (Blickwede 1991), L. Miocene of Aiveri 0.27%-.33% (Meinke 1987), Dramas 0.28%-0.31% (Kaouras et al.1991), Pliocene of Koroni's 0.325% (Antoniadis et al. 1992)).

COAL FACIES AND DEPOSITIONAL ENVIRONMENT

The composition of brown coal is influenced predominantly by the depositional setting, the type of vegetation, the nutrient supply to the vegetation, the level of ground water and the early diagenetic processes. 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.

Hacquebard and Donaldson (1969) were the first who developed a graphical, microlithotype based coal facies classification which incorporated the results of studies in Tertiary brown coals by Teichmueller (1956) and Teichmueller and Thompson (1958). In this facies diagram, seams or portions of seams are assigned to formation of the four moor facies of Teichmueller (1950). Hunt and co-authors have taken the study of coal palaeoenvironments beyond the immediate area of the depositional site and have studied the influence of tectonic and large scale depositional setting on the composition of coal. These studies have generally used microlithotype composition as the petrographic facies indicator.

Diesel (1982) made use of two facies triangles, similar to the approach of Hacquebard and Donaldson (1969). 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. 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. 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
B=Humodetrinite+Liptodetrinite+Mixinite+Sapropelinite+Alginite
C=Inetrinite

The interpreted depositional settings represented by the three apices are:

(A) forested swamp on the alluvial plain or at the junction of the alluvial plain and the upper delta plain, where middle oxic to middle anoxic conditions prevail and well preserved cell structure of organic constituents is characteristics.

(B) marsh or subaquatic lakes associated with a delta plain or barrier bar/strandplain, where depositional conditions are more anoxic than those for apex A, reed-marsh or aquatic vegetation dominates, and maceration and bacterial activity are than those for apex A: and(C) alluvial-plain, deltaplain, or strandplain oxic swamp affected by mouldering processes. Coals that formed in the swamp marsh complex on the upper delta plain lie between apices A and B.

RESULTS

In order to accomplish the purpose of this work, which is to perform a preliminary approach of the depositional environment of Lava's lignites, three of the coal facies diagrams that are already mentioned were used. To be more specific:

Figures 2a,b,c, illustrate the diagrams used, ABC introduced by Mukhopadhyay 1986, TFD introduced by Diesel 1982, and TPI-GI by Diesel 1986 respectively.

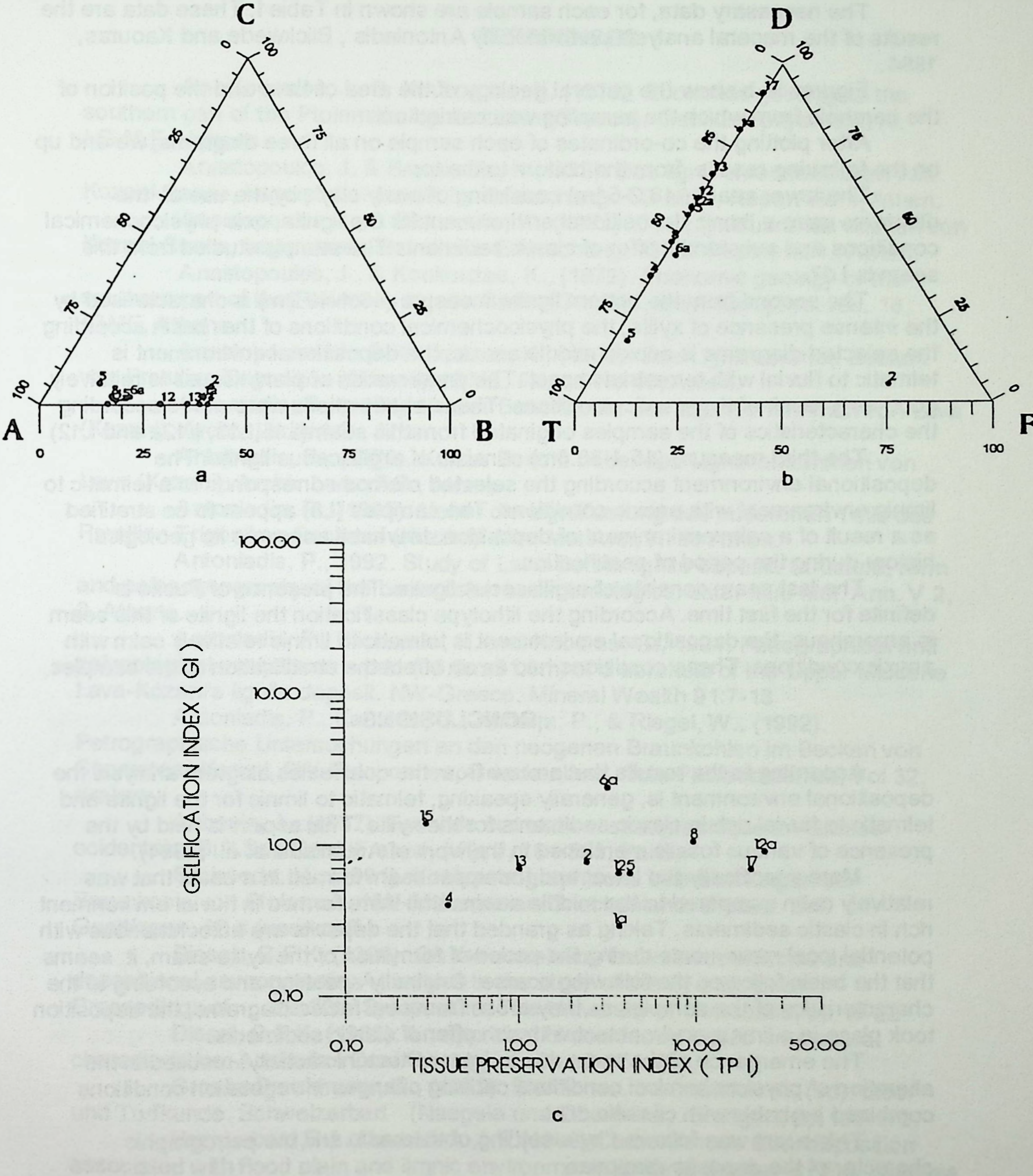


Figure 3. Determination of the depositional environment of Lava's lignite deposit using: a) the ternary diagram ABC modified by Mukhopadhyay, b) the ternary diagram TFD modified by Diesel (1982), c) the diagram GI–TPI modified by Diesel (1986). See text for explanations.

The necessary data, for each sample are shown in Table1. These data are the results of the maceral analysis performed by Antoniadis , Blickwede and Kaouras, 1994.

Figures1a.b show the general geology of the area of Lava and the position of the borehole from which the sampling was carried out.

After plotting the co-ordinates of each sample on all three diagrams, we end up on the following results, from the bottom to the top.

The lower seam (48.2-51m) consisting of coaly clay , by the use of the diagrams gave a limnic depositional environment for the lignite, oxic physicochemical conditions and substantial offer of clastic sediments.The sample studied from this seam is L17.

The second from the bottom lignite measure (45.4-48.2m) is characterised by the intense presence of xylite, the physicochemical conditions of the basin according the selected diagrams is anoxic-middle anoxic, the depositional environment is telmatic to fluvial with terrestrial impact. The preservation of plant tissues is relatively good as a result of the anoxic conditions. These observations were made according the characteristics of the samples originated from this seam(L15,L13, L12a and L12)

The third measure (45.4-38.8m) consists of argillaceous lignite. The depositional environment according the selected method corresponds to a telmatic to limnic environment with anoxic conditions. The samples (L8) appear to be stratified as a result of a calm environment of deposition. In what it concerns its geological history during the period of peatification.

The last seam consists of argillaceous lignite. The presence of Fusite is definite for the first time. According the lithotype classification the lignite of this seam is amorphous, the depositional environment is telmatic to limnic relatively calm with anoxic conditions. These conditions had as an effect the stratification of the samples.

CONCLUSIONS

According to the results that arouse from the coal facies diagram analysis the depositional environment is, generally speaking, telmatic to limnic for the lignite and telmatic to fluvial rich in clastic sediments for the xylite. This aspect is held by the presence of various fossils mentioned in the work of Antoniadis et el. (1994).

More specifically the lower and the upper seam formed in a basin that was relatively calm compared to the middle seams that were formed in fluvial environment rich in clastic sediments. Taking as granded that the deposits are autochthonous with potential local movements during the period of formation of the xylite seam, it seams that the basin followed the following coarse. Originally speaking and according to the characteristics of the samples as they arose from coal facies diagrams, the deposition took place in a limnic environment with rich offer of clastic sediments.

The emergence of the area, due to intense tectonic activity, resulted in the alteration of physicochemical conditions causing changes in vegetation conditions combined probable with climatic ones.

This event was followed by a settling of the basin and the petrographic character of the deposits reappear.

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DOCUMENTA NATURAE, 96 , S.13-24, 3 Abb., 1 Tab., München 1995

DEPOSITIONAL ENVIRONMENT INTERPRETATIONS BASED ON COAL FACIES ANALYSIS OF CHOMATERO-KORONI'S LIGNITE DEPOSIT (GREECE)

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Key Words: Chomatero-Koroni, Lignite, Coal Facies Diagramms, Depositional Environment, Physicochemical Conditions, Preservation of Plant Tissues, Forest Swamp

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ZUSAMMENFASSUNG

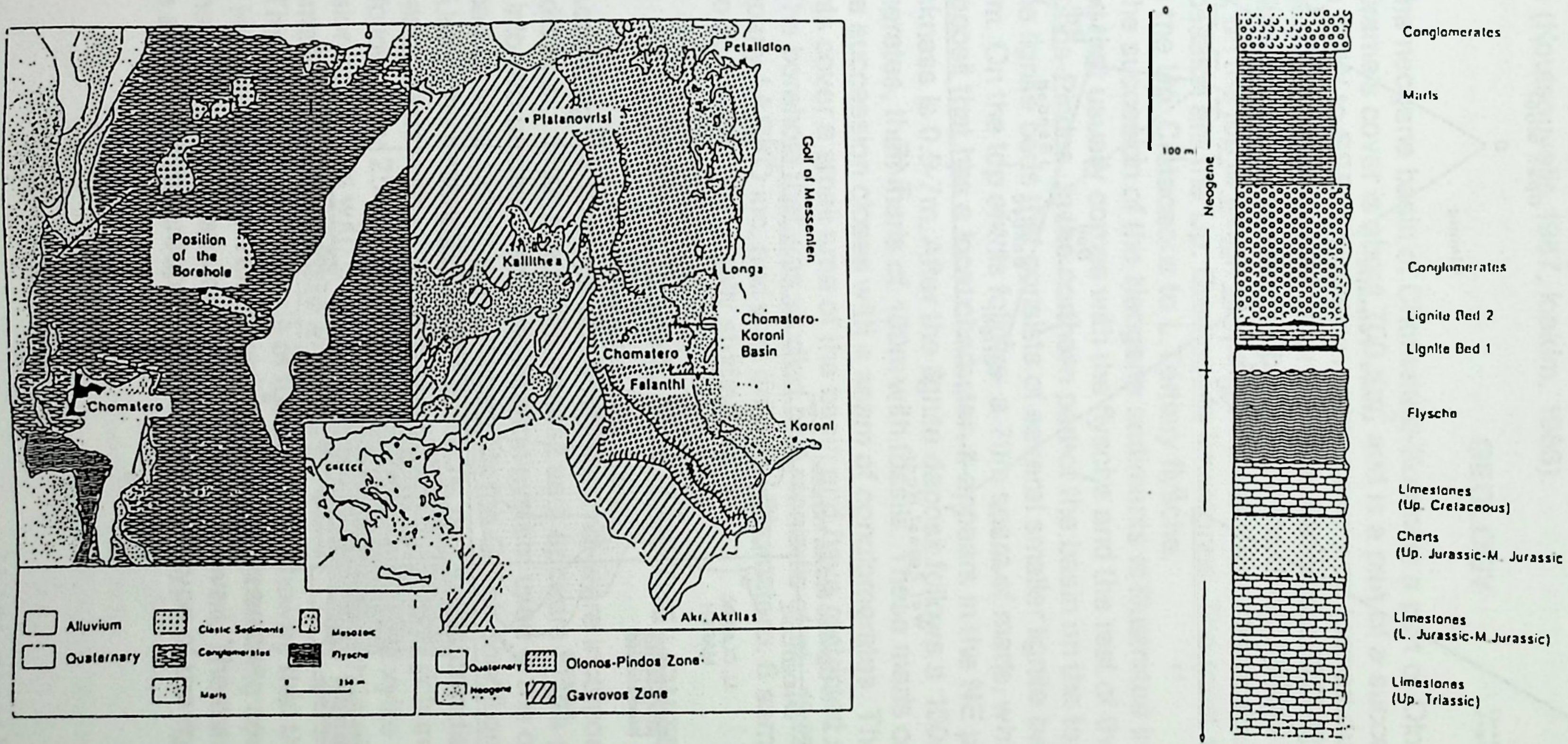
Die vorliegende Untersuchung bezieht sich auf die paläogeographischen Verhältnisse der Braunkohle-Flöze des Beckens von Chomatero-Koroni, (SW-Peloponnes, Griechenland). Hierzu werden die kohlepetrographischen Daten und auch die Arbeiten von Diesel (1982, 1986) und Mukhopadhyay (1986) verwendet. Auf diese Weise lassen sich Rückschlüsse auf die paläogeographischen Verhältnisse im Untersuchungsgebiet ziehen. Das Gebiet ist auch dafür prädestiniert,da der Versuch zu einer paläogeographischen Rekonstruktion bereits durch andere Methoden verifiziert wurde, und dadurch ein Vergleich der Ergebnisse ermöglicht wird. Zu diesem Zweck wurden die Daten aus 8 Proben einer repräsentativen Bohrung untersucht. Zusammenfassend für das Arbeitsgebiet kann man auf ein Riedmoor - Milieu schliessen.

ABSTRACT

This paper studies the characteristics and the depositional environment of Chomatero-Koroni's lignite deposits (Peloponnes, Greece). For this purpose the data from the petrographic analysis of 8 samples (Antoniadis et al. 1992) from a borehole drilled in the area were incorporated in this paper. Previous works (geological and petrographical) determined 2 lignite beds rich in mineral matter, xylite and plant relicts and of Pliocene of age. The present paper is an effort to determine the depositional environment of the Chomatero-Koroni's lignite deposits according the diagrammatic methods of Diesel (1982,1984) and Mukhopadhyay (1986). Simultaneously the results are compared to the classical methods (palaebotany and palynology) that are commonly used. Based on the rank determination the lignite is classified on the group of soft brown coals or on the transition stage of peat to lignite. Generally speaking the depositional environment according the method followed in the present paper and previous studies in the area proved to be forest swamp to open moor. The differences in the composition of the lignites are due to the vegetation and the depositional environment.

INTRODUCTION

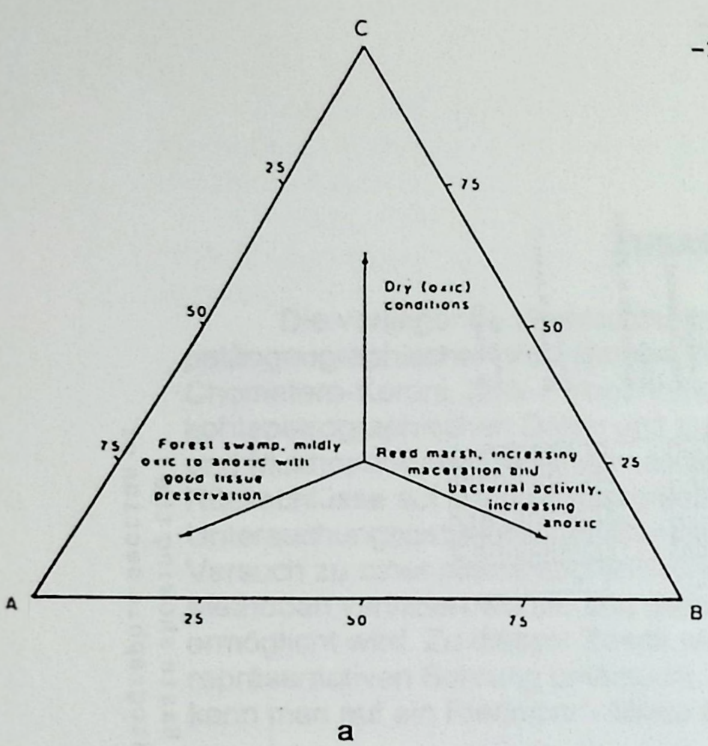
Chomatero-Koroni's lignite deposit is situated in Peloponnes. The depositional environment of these deposits was a matter of study several times (Fitrolakis, 1980, Albantakis, 1978, 1980, Karageorgiou 1951, Kaouras et al., 1993). During the period of 1939-1945 a restricted exploitation by small mines in Koroni and Falanthi took place. After various analyses the calorific value of the deposits is 3400Kcal/Kgr, the moisture content is 28.9 %, the tar 8.6%. These values correspond to a significant, in what it concerns the quality, lignite deposit. The present paper is a preliminary approach of the depositional environment of the Chomatero-Koroni's lignite deposit. For this purpose the data from the work of P. Antoniadis, G. Kaouras, P.A. Khanaqa,

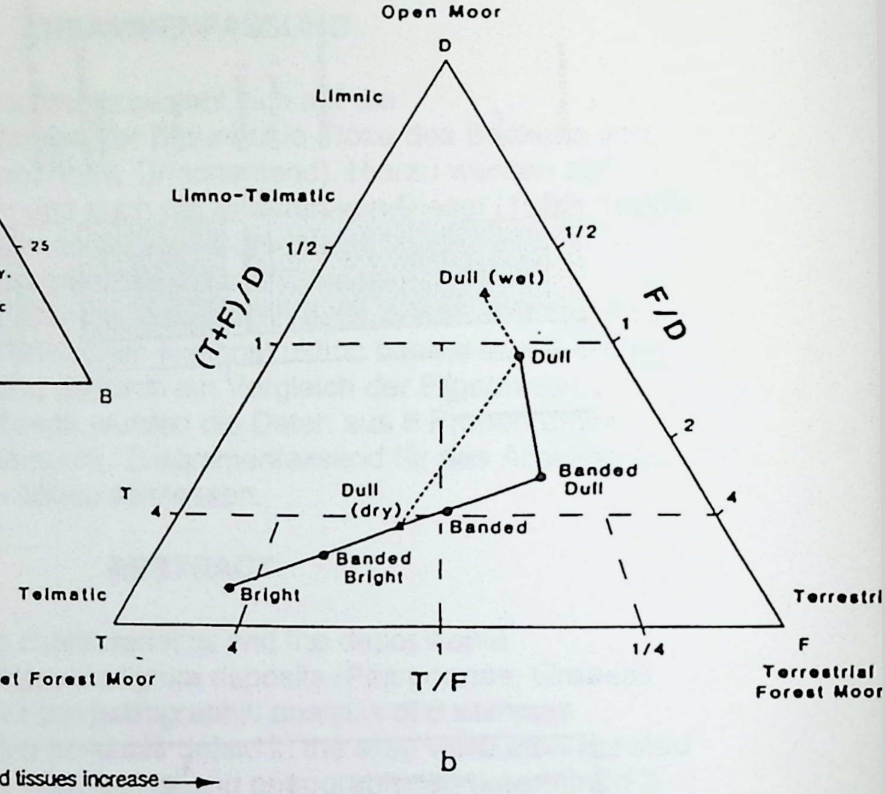


a

b

Figure 1. a) Geological map of the Chomatero-Koroni Basin showing the position of the borehole, b) Total stromatographic section of the area of the borehole.





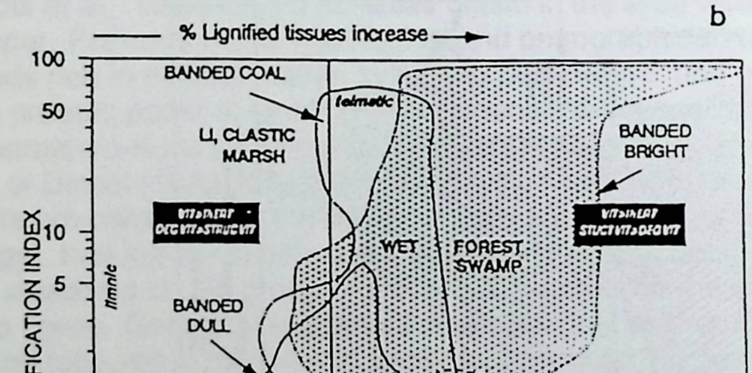


Figure 2. a) Ternary Diagram ABC illustrating suggested peat-forming environments, modified from Mukhopadhyay (1986) b) Ternary diagram TFD modified from Diesel (1982) c) Modified facies diagram GI-TPI from Diesel.

According the micropalaeontological data from marine sediments, that appear in the host the lignites sediments and the palynological study of the lignite seams from boreholes and field sampling of a small mining face, the age of the deposits is L. Pliocene (Koutsouvelis 1987, Ioakim, 1986).

GEOLOGY

The neogene basin of Chomatero-Koroni is a part of Olonos-Pindos zone. The size of Drama's cover is about 700 Km^2 and is a part of a succession of covers with direction NNW to SSE. The bottom of the cover was formed during L. Tertiary after a plunge of the area. The rocks older than the Neogene start with the Up. Tertiary thin bedded limestones. This seam is followed by the thick bedded limestones of the L.-M. Jurassic, on the top of which lie the Up.Jurassic to L.Cretaceous cherts. On the top of this succession are the Up. Createceous limestones. The most recent sediment of the profile is the Up. Cretaceous to L.Tertiary flysche.

The succesion of the Neogene sediments is illustrated in Figure 1a. It starts with sand that usually comes with the flysche and the rest of the sediments of the zone Olonos-Pindos. In the northern part of the basin on the top of the sand deposits lie the the lignite beds that consists of several smaller lignite beds. The total thickness is 10-20m. On the top of this follows a 70m seam of marls, which lies under the major lignite deposit that has a local character. It appears in the NE part of the basin and its total thickness is 0.5-7m. After the lignite deposit follows a 100m seam of conglomerates, then marls of 100m with fossils. These marls cover all the basin. The Neogene succession closes with a seam of conglomerates. The Quaternary sediments cover a small area of the basin and have restricted significance.

The borehole that was studied by Antoniadis et al., 1992 it was given away by the company LARKO inc. and was drilled in Chomatero. 8 samples were in total microscopically and chemically studied.

PETROGRAPHIC STUDY OF THE LIGNITE DEPOSIT.

According the lithotype analysis data, that were incorporated from the work of Antoniadis et al., 1992, the lignite deposit as it appears in this particulate borehole is divided into two unities. The classification system used is the one, that has been introduced by Vogt (1981) and adapted for the Greek conditions (Kaouras, 1989).

Using the description of the borehole profile (Antoniadis et al., 1992) the major lignite seam starts with a 30cm of an amorphous lignite rich in xylite and plant relicts. This is followed by 25 cm of xylitic lignite with 25-50% of xylite rich in plant relicts. The succession continues with 80cm of amorphous lignite rich in plant relicts, spores, roots, small fragments of xylite and fusite.

The microscopic analysis of the samples showed that the prevailing macerals are the Humotelinite and Humodetrinite. The Humocollinite content varies and riches the highest point in the seam where the marls prevail. The maceral content of the Liptinite and linertinite group vary according the type of the lignite.

PALYNOLOGY

The palynological data that aroused from previous works, carried out in the area (Antoniadis et al., 1992) conclude in the same results with the present paper and stand for the credibility of the method followed in this work.

RANK DETERMINATION

In the paper of Antoniadis et al.,1992, the determined rank of the deposits was 0.325%. That means that these lignites are classified on the borderline between peat and lignite or the class of the soft brown coals, exactly like the majority of the Greek deposits(Pleistocene deposit of Megalopoli 0.26%-0.31%, (Schonherr 1987), L. Miocene of Aiveri 0.27%-.33% (Meinke 1987).

COAL FACIES AND DEPOSITIONAL ENVIRONMENT

The composition of brown coal is influenced predominantly by the depositional setting, the type of vegetation, the nutrient supply to the vegetation, the level of ground water and the early diagenetic processes. 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.

Hacquebard and Donaldson (1969) were the first who developed a graphical, microlithotype based coal facies classification which incorporated the results of studies in Tertiary brown coals by Teichmueller (1956) and Teichmueller and Thompson (1958). In this facies diagram, seams or portions of seams are assigned to formation of the four moor facies of Teichmueller (1950). Hunt and co-authors have taken the study of coal palaeoenvironments beyond the immediate area of the depositional site and have studied the influence of tectonic and large scale depositional setting on the composition of coal. These studies have generally used microlithotype composition as the petrographic facies indicator.

Diesel (1982) made use of two facies triangles (fig 2a), similar to the approach of Hacquebard and Donaldson (1969). 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

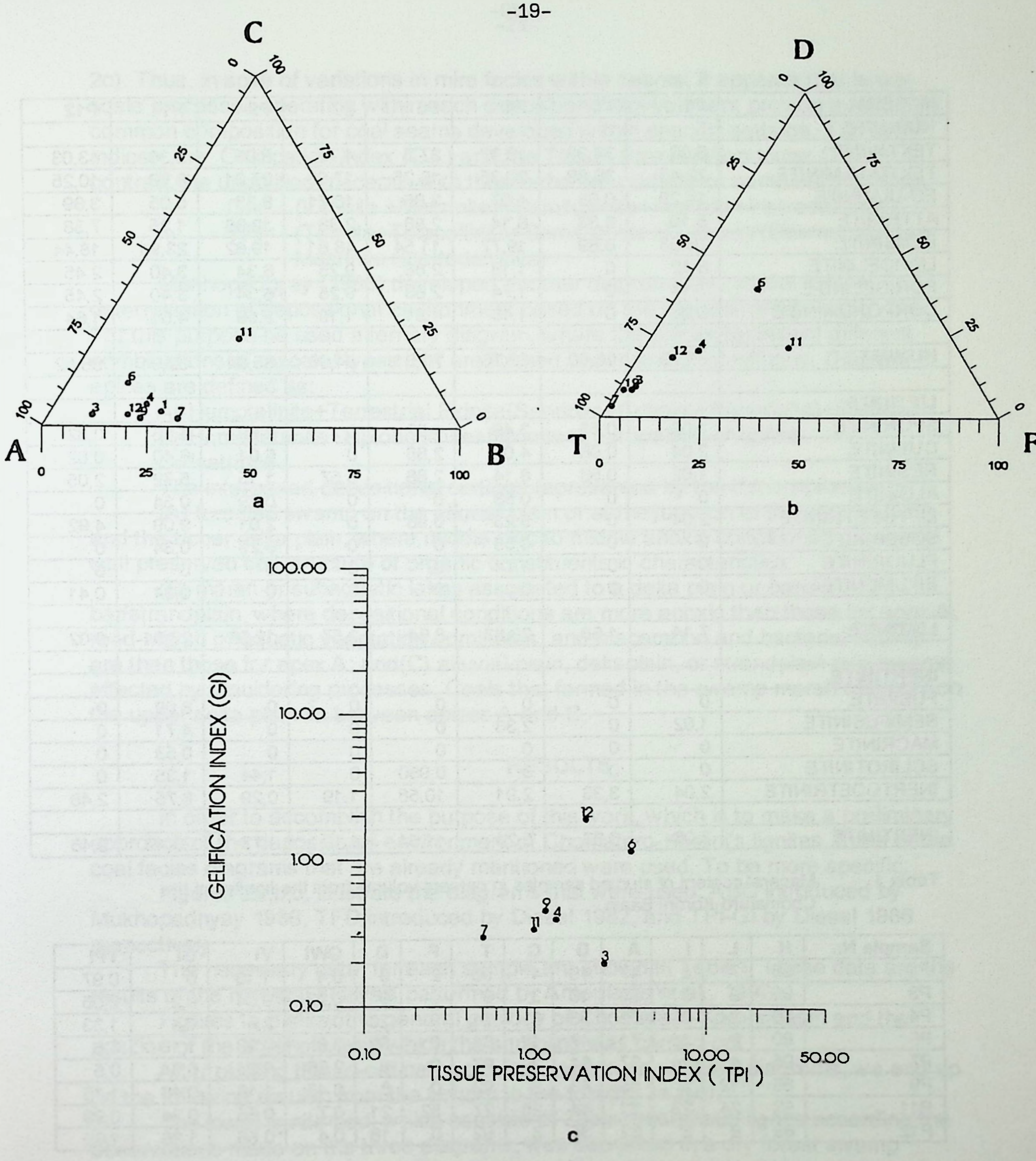


Figure 3. Determination of the depositional environment of Chomatero-Koroni's lignite deposit using: a) the ternary diagram ABC modified by Mukhopadhyay, b) the ternary diagram TFD modified by Diesel (1982), c) the diagram GI-TPI modified by Diesel (1986). See text for explanations.

MACERAL	P1	P3	P4	P6	P7	P9	P11	P12
HUMINITE								
TEXTINITE	3,06	38,33	13,37	37,5	4,76	8,05	2,36	43,03
TEXTO-ULMINITE	22,45	38,89	20,35	16,35	17,86	27,01	8,76	10,25
EU-ULMINITE	14,29	0,56	4,07	3,85	10,71	8,33	5,05	3,69
ATTRINITE	5,10	8,33	8,14	2,88	2,38	12,36	1,35	7,38
DENSINITE	26,53	8,89	19,77	11,54	48,81	19,82	23,91	18,44
LEVIGELINITE	6,12	0	1,16	2,88	9,25	6,34	3,40	2,45
PORIGELINITE	7,14	0	1,74	2,88	9,25	6,34	3,40	2,45
CORPOHUMINITE	3,06	0	1,16	4,81	1,19	2,59	4,04	1,64
HUMINITE	87,75	95,00	69,76	79,81	94,96	85,94	52,91	88,52
LIPTINITE								
SPORINITE	1,02	0,56	3,49	1,92	0	2,30	1,68	0,82
CUTINITE	2,04	0,56	4,07	2,88	0	6,61	6,40	0,82
RESINITE	1,02	0,56	8,14	2,88	3,57	1,15	5,72	2,05
ALGINITE	0	0	0,58	0	0	0,29	0,34	0
LIPTODETRINITE	2,04	0	5,23	0,96	0	2,01	9,09	4,92
SUBERINITE	0	0	0,58	0	0	0,29	0,34	0
FLUORINITE	0	0	1,74	0	0	0	0	0
BITUMENITE	0	0	0	0	0	0	0,34	0,41
LIPTINITE	7,14	1,68	23,83	8,64	3,57	12,36	23,91	9,02
INERTINITE								
FUSINITE	0	0	0	0	0	0	8,08	0
SEMIFUSINITE	1,02	0	2,33	0	0	0	4,71	0
MACRINITE	0	0	0	0	0	0	0,53	0
SCLIROTINITE	0	0	0	0,960	0	1,44	1,35	0
INERTODETRINITE	2,04	3,33	2,91	10,58	1,19	0,29	8,75	2,46
INERTINITE	3,06	3,33	5,24	11,54	1,19	1,73	23,42	2,46

Table 1. Maceral content of studied samples in percent volume from the lignites of the Chomatero-Koroni Basin.

Sample Nr.	H	L	I	A	B	C	T	F	D	GWI	VI	GI	TPI
P1	88	7	5	47	49	4	90	2	8	0,4	1,18	0	0,97
P3	95	2	3	79	18	3	91	0	9	0,23	0,04	0,2	2,55
P4	70	24	6	56	38	6	71	9	20	0,5	2,4	0,4	1,33
P6	80	9	11	71	17	12	61	0	39	0,5	0,98	1,18	3,6
P7	95	4	1	37	61	2	97	0	3	2,66	0,64	0,3	0,5
P9	86	12	2	55	43	2	92	0	8	0,45	1,16	0,46	1,15
P11	53	24	23	31	44	25	27	52	21	0,7	0,65	0,34	0,99
P12	89	9	2	62	35	3	82	0	18	0,4	0,58	1,36	1,95

Table 2. Distribution of maceral ratios and percentages as plotted in figures 2,3,4,5 and 6.

2c). 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. 2b). 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

B=Humodetrinite+Liptodetrinite+Mixinite+Sapropelinite+Alginite

C=Inetrinite

The interpreted depositional settings represented by the three apices are:

(A) forested swamp on the alluvial plain or at the junction of the alluvial plain and the upper delta plain, where middle oxic to middle anoxic conditions prevail and well preserved cell structure of organic constituents is characteristics.

(B) marsh or subaquatic lakes associated to a delta plain or barrier bar/strandplain, where depositional conditions are more anoxic than those for apex A, reed-marsh or aquatic vegetation dominates, and maceration and bacterial activity are than those for apex A: and(C) alluvial-plain, deltaplain, or strandplain oxic swamp affected by mouldering processes. Coals that formed in the swamp marsh complex on the upper delta plain lie between apices A and B.

RESULTS

In order to accomplish the purpose of this work, which is to make a preliminary approach of the depositional environment of Chomatero-Koroni's lignites, three of the coal facies diagrams that are already mentioned were used. To be more specific:

Figures 2a,b,c, illustrate the diagrams that were used, ABC introduced by Mukhopadhyay 1986, TFD introduced by Diesel 1982, and TPI-GI by Diesel 1986 respectively.

The necessary data, for each sample are shown in Table1. These data are the results of the maceral analysis performed by Antoniadis et al., 1992.

Figures 1a,b show the general geology of Chomatero-Koroni basin and the position of the borehole from which the sampling was carried out.

After plotting the co-ordinates of each sample on all three diagrams, we end up on the following results, from the bottom to the top (fig 3a,b,c):

The lower lignite bed, which consists of 30cm amorphous lignite according the observations made on the three diagrams, was deposited in a dry forest swamp where the physicochemical conditions were midlle oxic to anoxic, with good tissue preservation and macerals like textinite. Deviation shows sample 12 which a fibrous lignite probably deposited in wet forest swamp. The depositional environment proved to be telmatic to limnotelmatic with restricted terrestrial impact. Sample 11 from the same seam is deposited in an environment where the role of bacteria is more important, having as result the destruction of the plant tissues. The middle seam is represented in this study by the characteristics of sample 9. It corresponds to dry forest swamp environment, being rich in xylite and plant tissues. The last seam is amorphous lignite, which depositional environment is the same to the lower seam apart of sample 6, which is deposited in an environment where the offer of fresh water was significant, most probably limnic. The type of the lignite in this position is fibrous.

CONCLUSIONS

According to the results that arouse from the coal facies diagrams analysis the depositional environment is, generally speaking, limnotelmatic to limnic and more specifically it concerns a forest swamp, which occasionally was flood by fresh water. This aspect is held by the presence of various fossils mentioned in the work of Antoniadis et al. (1992).

More specifically the whole profile seem to have deposited in a telmatic to limnic environment. The physicochemical conditions are middle oxic to anoxic with good tissue preservation. These conditions had as a result the preservation of the plant tissues, which is represented by the definite presence of macerals like Textinite and Texto-ulminite. Deviation from this model appears the lower seam, which seams that was deposited under more wet conditions sample 11,12 and a part of the upper seam, where sample 6 was taken. It seams that we are dealing with a close basin which occationally was flood by fresh water.

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DOCUMENTA NATURAE, 96 , S.25-34, 3 Abb., München 1995

DEPOSITIONAL ENVIRONMENT INTERPRETATIONS BASED ON COAL FACIES ANALYSIS OF DRAMA'S LIGNITE DEPOSIT (GREECE)

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Key Words: Drama, Lignite, Coal Facies Diagramms, Depositional Environment, Physicochemical Conditions, Preservation of Plant Tissues, Limnotelmatic to Limnic Environment

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ZUSAMMENFASSUNG

Die vorliegende Arbeit bezieht sich auf die paläogeographischen Verhältnisse der Braunkohle-Flöze des Beckens von Drama in Ostmakedonien, die vermutlich die nördlichen Ausläufer tieferer Teile des Torfes von Philippi sind. Hierzu werden zunächst einmal kohlepetrographische Daten sowie die Arbeiten von Diesel (1982, 1986) und Mukhopadhyay (1986) verwendet und so auf die paläogeographischen Verhältnisse im Untersuchungsgebiet geschlossen. Letzteres bietet sich von selbst an,da der Versuch zu einer paläogeographischen Rekonstruktion bereits durch andere Methoden erarbeitet wurde. Zu diesem Zweck wurden die Ergebnisse aus 9 Proben einer repräsentativen Bohrung beleuchtet. Zusammenfassend für das Arbeitsgebiet kann man auf ein wechselndes Milieu von limno-telmatischen zu limnischen Bedingungen schließen.

ABSTRACT

This paper studies the characteristics and the depositional environment of Drama's lignite deposits in eastern Macedonia. For this purpose the data from the petrographic analysis of 9 samples (Kaouras et al. 1991) from a borehole drilled in the area were incorporated in this paper. Previous works in the area (geological and petrographical) determined 3 lignite beds rich in mineral matter and of Pleistocene age. The present paper is an effort to determine the depositional environment of Drama's lignite deposits according the diagrammatic methods of Diesel (1982,1984) and Mukhopadhyay (1986). Simultaneously the results are compared to the classical methods (palaeobotany and palynology) that are commonly used. Based on the rank determination the lignite is classified on the group of soft brown coals or on the transition stage of peat to lignite. Generally speaking the depositional environment according the method followed in the present paper and previous studies in the area proved to be limnotelmatic to limnic. The differences in the composition of the lignites are due to the vegetation and the depositional environment.

INTRODUCTION

Drama's lignite deposit is situated in eastern Macedonia. Extenive lignite deposits proved that exist in the ground of Drama's basin. The present paper is a preliminary approach of the depositional environment of the Drama's lignite deposits. For this purpose the data from the work of G. Kaouras, P. Antoniadis, H. Blickwede, W. Riegel 1991 « Petrographische und Palynologische Untersuchungen an Braunkohlen im Becken von Drama». This paper is a palynological and petrographical approach using a series of samples from a borehole drilled in the area by P.P.C. with the purpose of studying the lignite deposits of the area. This particulate deposit consists of three lignite beds with total thickness of 9m and considerable percentage of mineral matter. The dominant maceral is Humodentrinite and, occasionally xylite. On the basis of rank determination, which is relatively low, these deposits are classified on the borderline between peat and lignite.

and, occasionally xylite. On the basis of rank determination, which is relatively low, these deposits are classified on the borderline between peat and lignite.

The palynological study of the paper of Kaouras et al. (1991) showed a limnic depositional environment. The upper seam, which is the richest in organic matter formed during a warm period of Middle Pleistocene.

Recently within a research program of the Institute of Geology and Mineral Exploration (I.G.M.E.) and P.P.C. a large number of boreholes were drilled in order to estimate the reserves, the profitability and the possible uses of the deposit. Thus, it was proved that underneath the Pleistocene cover in the area, lie significant lignite deposits. It concerns an elongation of the deepest part of Philippi peat.

GEOLOGY

The size of Drama's cover is about 700 Km^2 and is a part of a succession of covers with direction NNW to SSE. The bottom of the cover was formed during L. Tertiary after a plunge of the area. The present state of the cover was formed during the Neogene and the Quaternary.

Despite the fact that the two adjoining covers, the one of Strimone to the West and the other of Xanthi to the East that end up in the Aegean sea, several times undertook trangressions and flood, Drama's cover was protected by the mountains of Paggeon (marbles and gneiss) and Simbolo (Kavala's granite). The northerner part of the cover consist of Mesozoic marbles.

The succession of the Neogene sediments of Drama's cover is not studied yet. According unpublished geophysical researches the base of the cover lies at about 200m. The succession of the sediments is similar to that of Strimona's cover where the coarse clastic limnic sediments prevail and they are followed by carbonaceous sediments of fresh water, clays and hard xylitic coals. These seams consist the base of the major succession and they are followed by red sediments and are probably formed during Messinion.

The profiles studied by Teichmueller (1969) consist of a succession of alternated limnic clays and peat of 130m thickness, underneath of which appear the Pleistocene seams that consist of clays and marls. On the top of the succession follow 65m of peat, where the last 5m are of Holocene age.

The borehole where the sampling took place was drilled 10 Km from this area. (Fig. 1). The seams where the lignite beds appear lie in depth of 120-160Km. Deeper are found other insignificant lignite beds. The results of the research correlate these deposits to the peat of Philippi. To the north the deposits loose their financial importance and they are transformed to argillaceous lignites.

PETROGRAPHIC STUDY OF THE LIGNITE DEPOSIT.

According the lithotype analysis data, that were incorporated from the work of Kaouras et al.,1991, the lignite deposit as it appears in this particulate borehole is divided into three unities. The classification system used is the one, that has been introduced by Vogt (1981) and adapted for the Greek conditions (Kaouras, 1989). The lower lignite bed appears at 154-159.8m depth. The actual lignite bed appears at 156.5-159.8, the rest are the host sediments. The lower unity consists of argillaceous coal and carbonaceous clays. The organic constituents of the lignite beds are plant relicts, spores and fusinite. The higher part of this unity consists of

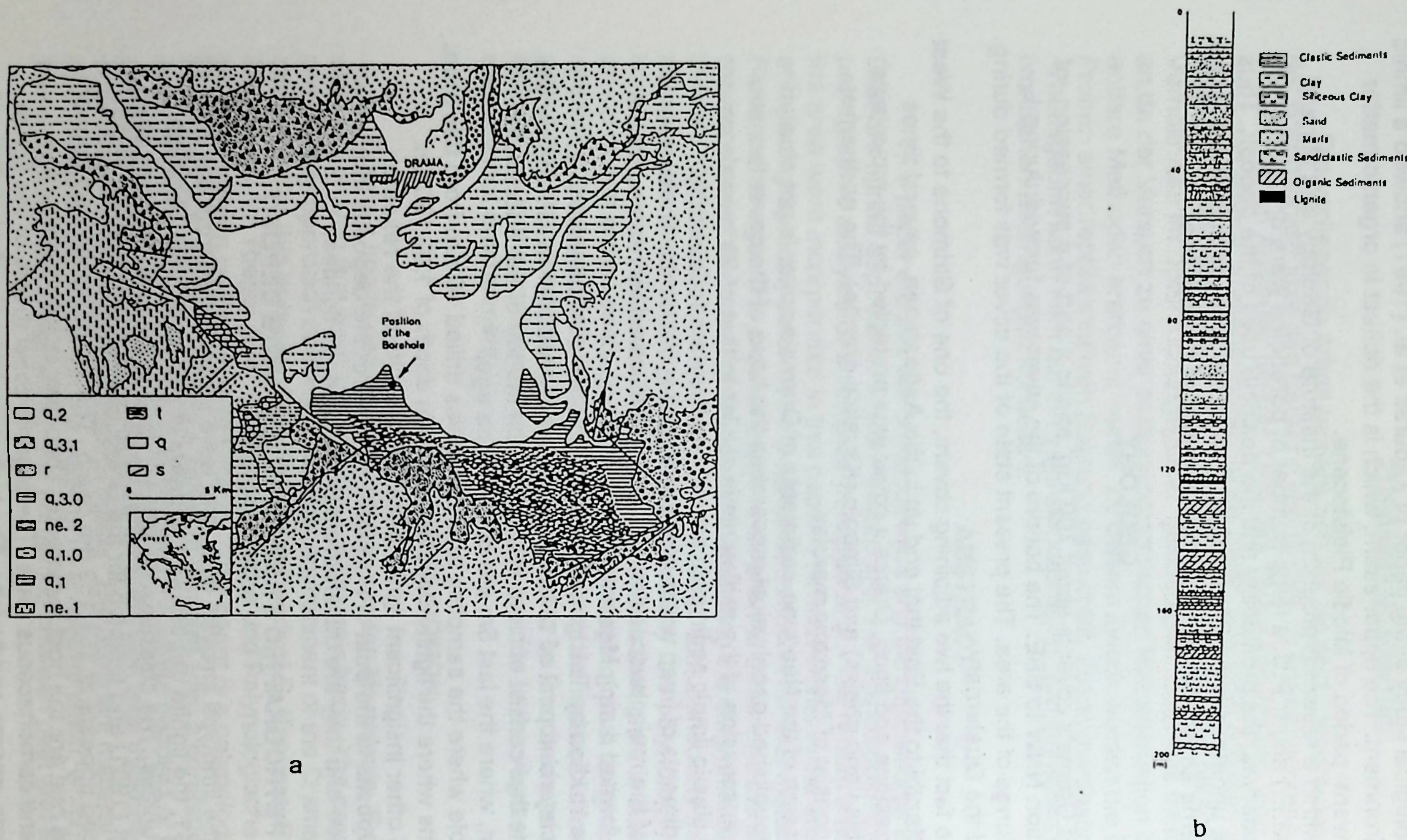

Fig.1: a) Geological map of the Drama basin showing position of the studied borehole. Explanations of legend : q.2-delta deposits; q.3.1-conglomerates; r.-crystalline rocks; q.3.0-lacustrine deposits; ne.2-lacustrine marls and conglomerates ; q.1.0-lacustrine, terrestrial deposits; q.1-brownish red silty clay with pebbles; ne.1-marine to brackish deposits; t-peat; q-Quaternary; s-fault. b) Diagram showing total section of the studied borehole.

carbonaceous marls rich in plant relicts. The middle unity appears at 142.5-149,7m. In this unity, where various plant relicts, fusinite and xylite appear, occurs a significant bed of coaly clays in conglomerates and sandstones. The upper unity is the more significant

and contains a high quality lignite. It appears at depth 122-132,7m and apart of fusinite and plant relicts there are roots and plant leaves.

On the basis of the maceral analysis within the framework of the before mentioned work the prevailing maceral group is huminite. Only samples D7 and D12, that petrographically are argillaceous coals and appear in the upper part of the middle unity, show a deviation from this model of depositional environment. In the liptinite group prevails liptodetrinite which is the clastic member of this maceral type, the same situation stands for the inertinite group where the inertodetrinite prevails.

PALYNOLOGY

The palynological data that aroused from previous works, carried out in the area (Kaouras, G., 1991, Antoniadis, et al. 1992) conclude in the same results with the present paper and stand for the credibility of the method followed in this work.

RANK DETERMINATION

In the paper of Kaouras et al.,1991, the determined rank of the deposits was 0.28-0.31%. That means that these lignites are classified on the borderline between peat and lignite or the class of the soft brown coals, exactly like the majority of the Greek deposits(Pleistocene deposit of Megalopoli 0.26%-0.31%, (Schonherr 1987), L. Miocene of Aiveri 0.27%-.33% (Meinke 1987).

COAL FACIES AND DEPOSITIONAL ENVIRONMENT

The composition of brown coal is influenced predominantly by the depositional setting, the type of vegetation, the nutrient supply to the vegetation, the level of ground water and the early diagenetic processes. 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.

Hacquebard and Donaldson (1969) were the first who developed a graphical, microlithotype based coal facies classification which incorporated the results of studies in Tertiary brown coals by Teichmueller (1956) and Teichmueller and Thompson (1958). In this facies diagram, seams or portions of seams are assigned to formation of the four moor facies of Teichmueller (1950). Hunt and co-authors have taken the study of coal palaeoenvironments beyond the immediate area of the depositional site and have studied the influence of tectonic and large scale depositional setting on the composition of coal.These studies have generally used microlithotype composition as the petrographic facies indicator.

Diesel (1982) made use of two facies triangles (fig 2a), similar to the approach of Hacquebard and Donaldson (1969). Initially the diagnostic macerals are compared to the remaining organic components of the seam by grouping the maceral content as follows:

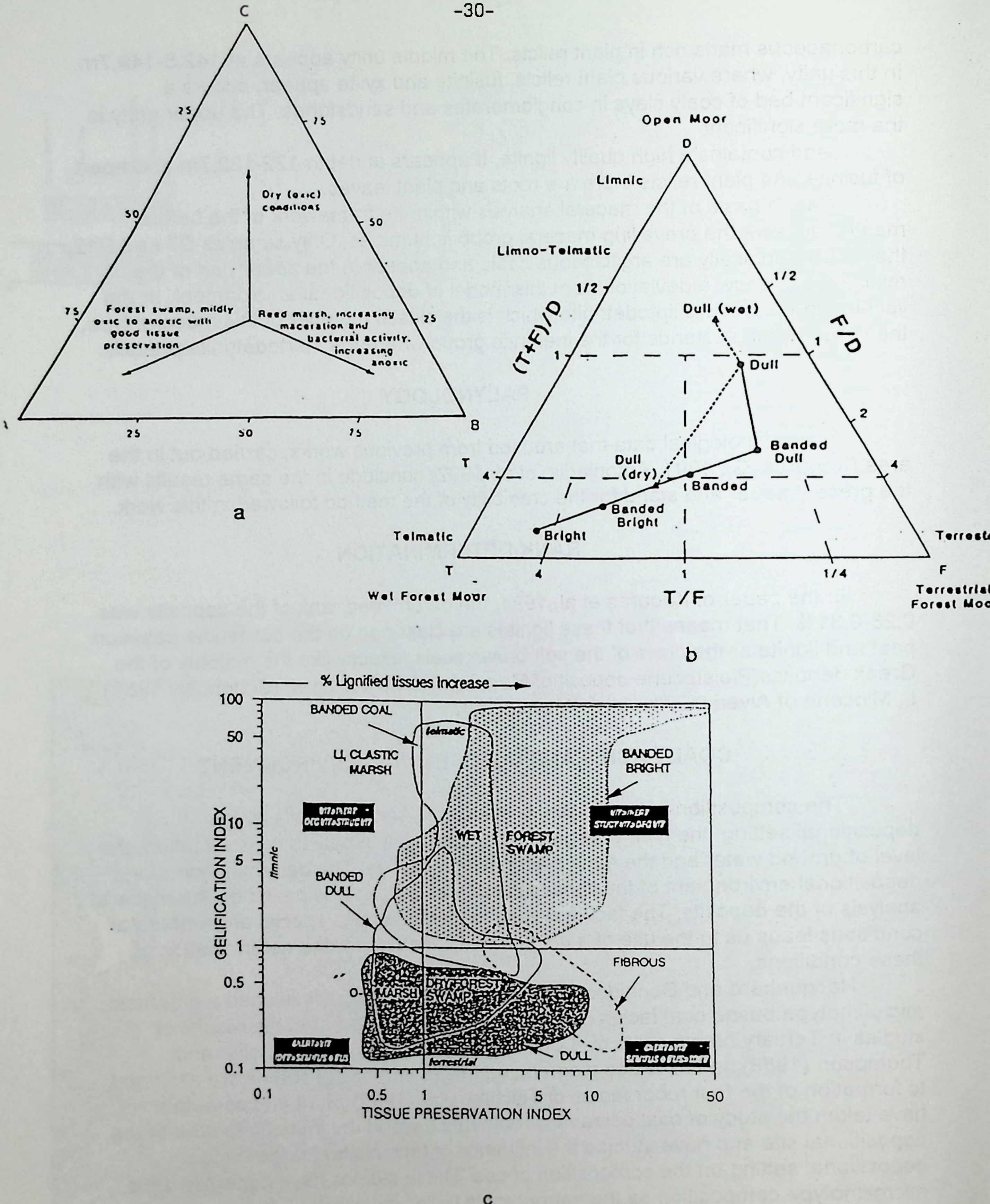

Figure 2. a) Ternary Diagram ABC illustrating suggested peat-forming environments, modified from Mukhopadhyay (1986) b) Ternary diagram TFD modified from Diesel (1982) c) Modified facies diagram GI-TPI from Diesel.

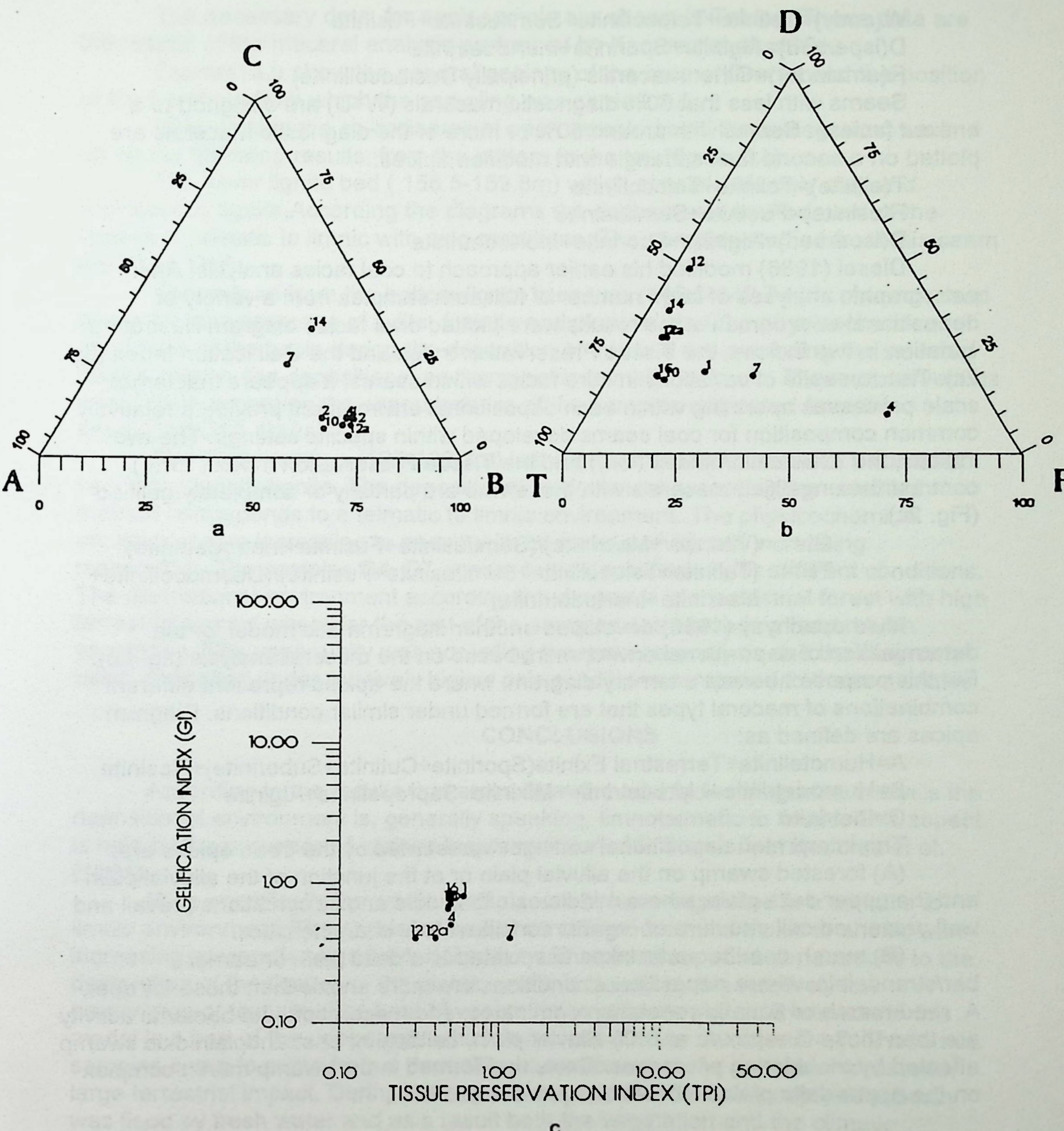

Figure 3. Determination of the depositional environment of Drama's lignite deposit using: a) the ternary diagram ABC modified by Mukhopadhyay, b) the ternary diagram TFD modified by Diesel (1982). c) the diagram GI-TPI modified by Diesel (1986). See text for explanations.

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 2c). 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 (Fig. 2c).

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. 2b). 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
B=Humodetrinite+Liptodetrinite+Mixinite+Sapropelinite+Alginite
C=Inetrinite

The interpreted depositional settings represented by the three apices are:

(A) forested swamp on the alluvial plain or at the junction of the alluvial plain and the upper delta plain, where middle oxic to middle anoxic conditions prevail and well preserved cell structure of organic constituents is characteristics.

(B) marsh or subaquatic lakes associated to a delta plain or barrier bar/strandplain, where depositional conditions are more anoxic than those for apex A, reed-marsh or aquatic vegetation dominates, and maceration and bacterial activity are than those for apex A: and(C) alluvial-plain, deltaplain, or strandplain oxic swamp affected by mouldering processes. Coals that formed in the swamp marsh complex on the upper delta plain lie between apices A and B.

RESULTS

In order to accomplish the purpose of this work, which is to make a preliminary approach of the depositional environment of Drama's lignites, three of the coal facies diagrams that are already mentioned were used. To be more specific:

Figures 2a,b,c, illustrate the diagrams that were used, ABC introduced by Mukhopadhyay 1986, TFD introduced by Diesel 1982, and TPI-GI by Diesel 1986 respectively.

The necessary data, for each sample are shown in Table1. These data are the results of the maceral analysis performed by Kaouras et al., 1991.

Figures1a,b show the general geology of the area of Drama and the position of the borehole from which the sampling was carried out.

After plotting the co-ordinates of each sample on all three diagrams, we end up on the following results, from the bottom to the top (fig 3a,b,c):

The lower lignite bed (156.5-159.8m) which consists of coaly clay and argillaceous lignite.According the diagrams the depositional environment of the lignites is telmatic to limnic with oxic conditions. The samples studied from this seam are D14, D16.

The second from the bottom lignite measure (142.5-149.7m) is characterised by the intense presence of xylite, fusinite and plant relicts. The physicochemical conditions of the basin during the deposition of this bed are according the selected diagrams oxic, the depositional environment is telmatic to limnic. These observations were made according the characteristics of the samples originated from this seam(D10,D12, D12a).

The third measure (122-132.7m) is the most important, because it contains very good quality lignite. The depositional environment according the selected method corresponds to a telmatic to limnic environment. The physicochemical conditions were increasing to anoxic with bacterial activity and increasing maceration. The samples D4, D7 appear to be deposited under different conditions. The depositional environment according the diagrams is a terrestrial forest with high terrestrial impact where for the rest of the samples corresponds a reed marsh vegetation. The upper unity was according the maceral analysis and the diagrams used, deposited under relatively higher oxic conditions compared to the rest unities .

CONCLUSIONS

According to the results that arose from the coal facies diagrams analysis the depositional environment is, generally speaking, limnotelmatic to limnic. This aspect is held by the presence of various fossils mentioned in the work of Kaouras et el. (1991).

More specifically the whole profile seem to have deposited in a telmatic to limnic environment. The physicochemical conditions are middle oxic to anoxic with increasing maceration and bacterial activity. The presence of bacteria results to the destruction of the tissues of the plants, and this is held by the relatively low percentage of textinite. The type of vegetation is of lower plants. Exception to this model is a part of the upper unity which is represented by samples D4,7. These two samples seam to come from a depositional environment of a terrestrial forest with large terrestrial impact. During the deposition period of the two samples the basin was flood by fresh water and as a result both the vegetation and the climatic conditions changed.

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DOCUMENTA NATURAE, 96 , S.35-43, 2 Abb., München 1995

GEOLOGY OF THE AMYNTEON MAIN LIGNITE DEPOSIT - a preliminary report

P.Antoniadis & E. Lampropoulou

INTRODUCTION

This paper is based upon the geological data of a representative borehole, that was drilled in the area of the major deposit of Amynteon. Another paper, which is in print, studies the borehole data of Apofysis-Amynteon deposit; this deposit is the elongation of the lignite deposit that is studied in the present work. With the present paper a more complete picture of the Amynteon deposit is given.

The most important published work that was carried out in this area was from Koukouzas et al. (1979).

Special thanks deserve from the authors : N. Athanassiou, Dir. of the Research Dept. of P.P.C. and the geologists, Kyriakides and Kalatzopoulos for all the facilities that they provide us during the sampling procedure.

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Geology of the Amynteon main lignite deposit

The area of Amynteon is a part of the same geological settings with the area of Ptolemais, which its sequence is disrupted by large scale tectonic movements that took place later during the Quaternary period. 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-Petron, Amynteon.

Base formations

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.

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.

Grate metapliocene faults raised parts of the basement on the surface.

Neogene sediments

With the term neogen sediments are characterised either lignitic or not sediments that filled the basin after the formation of the tectonic deep.The neogen sediments are divided to two discrete seams that differ to 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. For the lower neogen is Lower Pliocene to Upper Miocene, it seems there is continuation between them. After the formation of the Pliocene sediments important tectonic movements took place. As a result tectonic rifts and hights were formed. These movements which transform Ptolemais basin and because of them the deeps of Chimaditidas, Vegoras, Zari and Petron were formed are of NE-SW direction. The same movements contribute to the formation of the NW part of Ptolemais basin part of which is the Amynteon deposit.

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 Blanorbis and Vivipara appears. Towards the centre of the basin the limestones turns to marls with the same fossils. A general characteristic

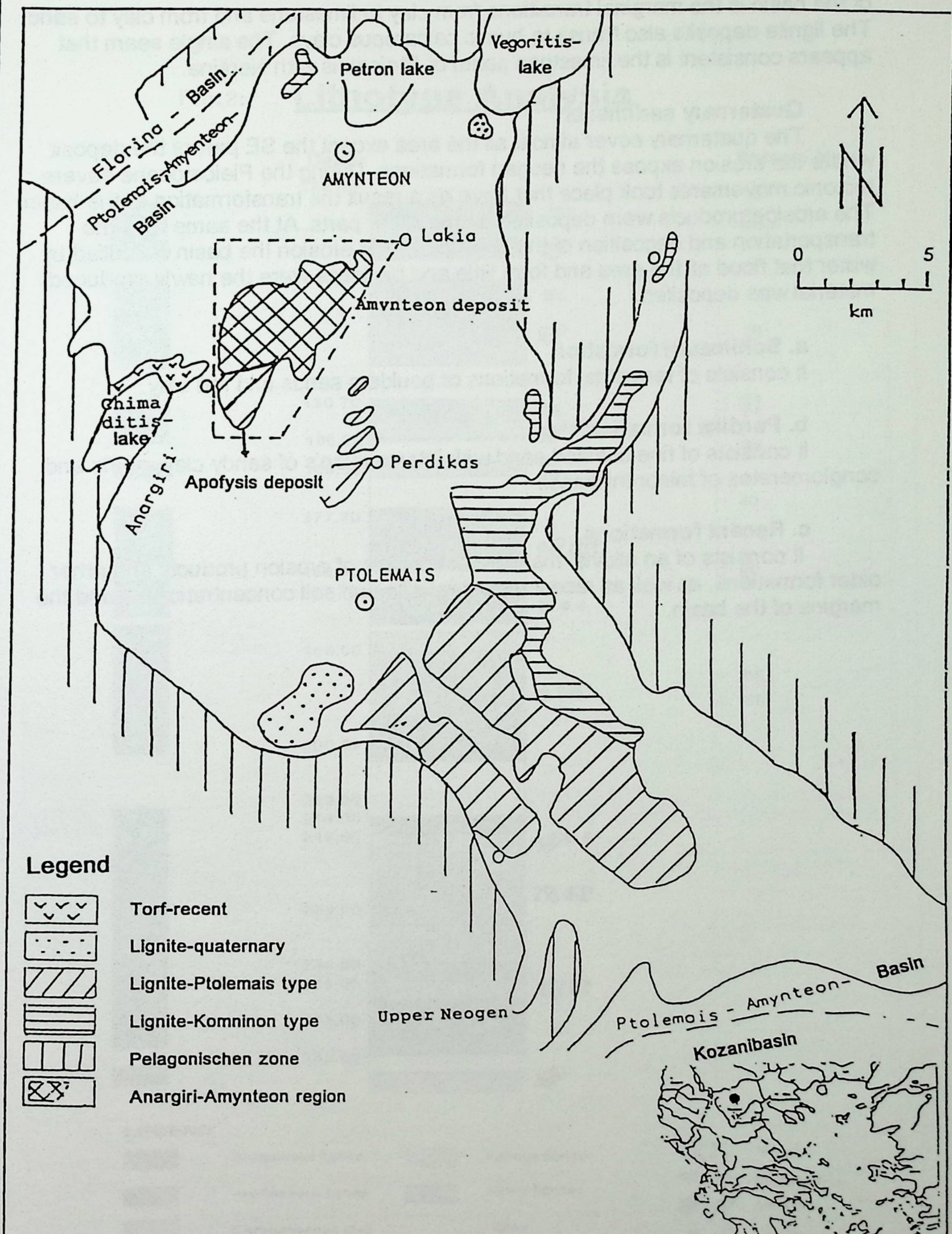


Fig.1: Geological Map according Koukouzas et al. (from P.P.C., Archiv)

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.

Quaternary sediments.

The quaternary cover almost all the area except the SE part of the deposit where the erosion expose the neogen formations. 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.

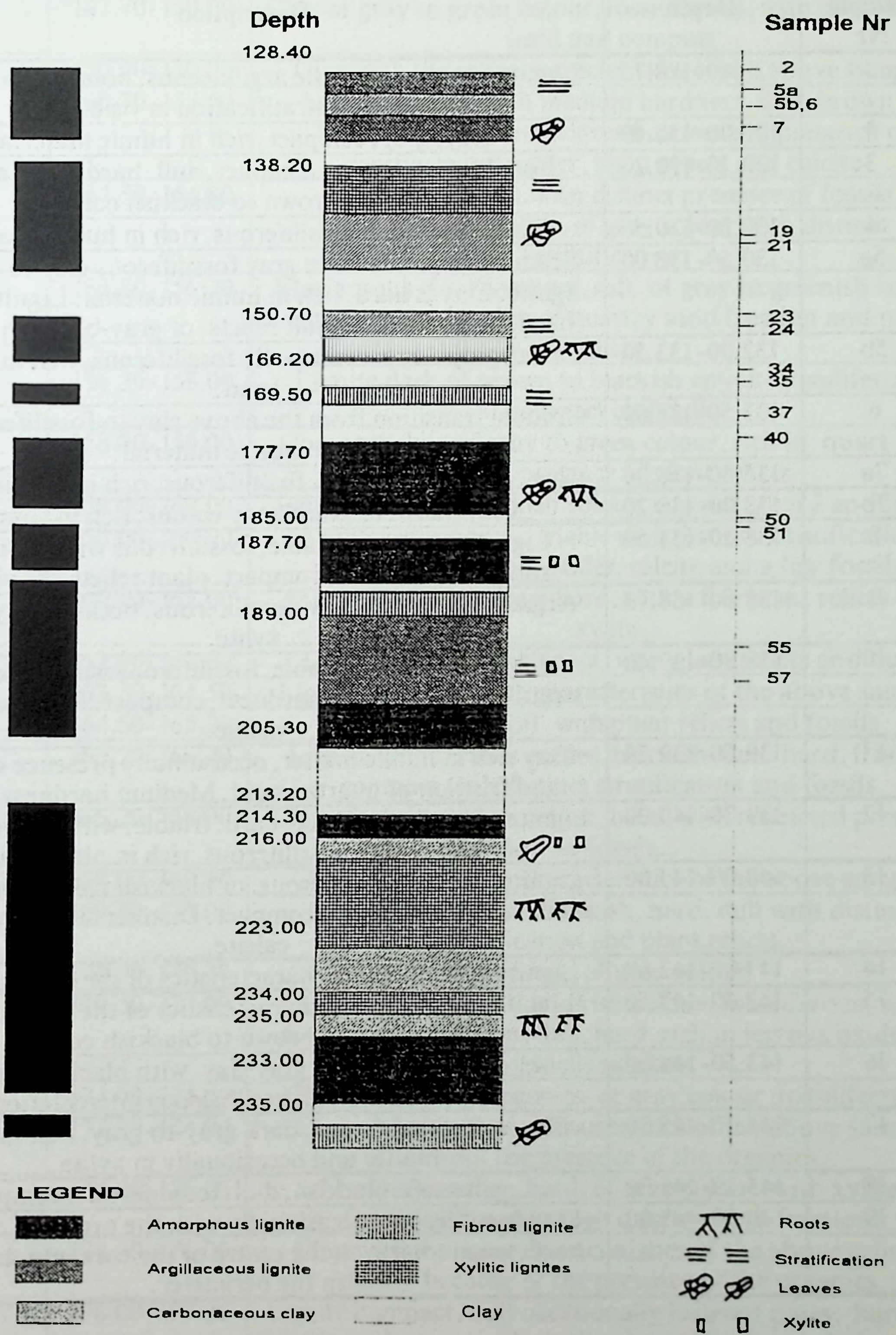
b. Perdika formation

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

c. Recent formations.

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.

Fig.2: **Lithotype Analysis**



DESCRIPTION OF THE SAMPLES FROM THE BOREHOLE B-258 OF AMYNTEON

Sample Nr	Depth	Description
1	128.40-128.75	Lignite friable, soft, little argillaceous, homogeneous, dull. Distinct stratification is visible.
2	129.00-130.10	Clay, grey, compact, rich in humic material.
3	130.10-130.20	Fossiliferous lignite, compact, dull, hard, rich in plant relicts, of brown to blackish colour.
4	130.20-130.50	Clay, gray, hard, fossiliferous, rich in humic material.
5a	130.50-132.00	Gradual transition from gray fossiliferous clay to compact lignite. Clay is hard, rich in humic material. Lignite is also hard, friable rich in plant relicts, of gray-blackish colour.
5b	132.00-133.50	Green-gray clay, occasionally fossiliferous, rich in quartzy sand.
6	133.50-135.00	Gradual transition from the above clay to fossiliferous clay rich in humic material.
7a	135.00-138.00	Clay, gray, occasionally fossiliferous, rich in humic matter.
7b	138.00-138.20	Clay, hard, of green-gray colour, rich in fossils.
8	138.20-138.50	Lignite, compact, friable, fossiliferous with indistinct stratification, hard, compact, plant relicts are visible.
9	138.50-138.75	Argillaceous marl, gray, fossiliferous, occasionally rich in xylite
10	138.80-139.40	Lignite compact, friable, fossiliferous with indistinct stratification, medium hardness, compact. Plant relicts are visible.
11	139.50-139.70	Clay rich in humic matter, occasionally presence of xylite and fraction of quartzy sand. Medium hardness, gray.
12	139.70-140.00	Lignite of blackish colour, hard, friable, with intercalations of quartzy clay, fossiliferous, rich in plant relicts.
13	140.00-141.00	Lignite, friable, fossiliferous, of blackish colour, dull, with indistinct stratification, compact. Distinct is the presence of calcite.
14	141.00-142.69	Lignite with the same characteristics of the above sample.
15	142.60-143.50	Lignite with the same characteristics of the above sample but harder, of brown to blackish colour.
16	143.50-144.00	Alternation of hard, gray clay with blackish lignite, compact, dull, with argillaceous intercalations.
17	144.00-145.30	Clay soft, fossiliferous, dark gray-to gray, rich in humic matter and occasionally in xylite.
18	145.30-146.30	Lignite soft, blackish, dull, fossiliferous, compact.
19	146.30-147.00	Clay fossiliferous, occasionally with the presence of xylite, hard, green to gray in the centre of the core and dark gray in the perimeter.

20	147.20-147.70	Lignite, blackish, dull, hard and friable. Rich in pyrite, with distinct smell of sulphur. The stratification is indistinct and is rich in plant relicts.
21a	147.70-150.00	Clay of gray to green colour, fossiliferous, with plant relicts, hard and compact
21b	150.00-150.70	Clay with the same characteristics of the above sample.
22	150.70-151.50	Lignite friable, with medium hardness, dull, brown to blackish with distinct stratification and presence of argillaceous matter, plant relicts and calcite.
23	151.50-154.80	Lignite soft, dull, with distinct presence of fossils, argillaceous matter, of gray colour with distinct stratification.
24	154.80-156.20	Marlaceous clay, compact, soft, of gray to greenish colour with high proportion of quartzy sand fraction and plant relicts.
25	156.20-158.00	Lignite dark of brown to blackish colour, fossiliferous, compact and dull.
26	158.00-159.00	Compact clay, of gray to green colour, rich in quart with distinct presence of plant relicts.
27	159.00-160.00	Lignite brown to blackish colour, compact, hard and friable.
28	160.00-160.90	Argillaceous lignite, friable with distinct stratification, presence of ferrous oxides, calcite and a few fossils.
29	160.90-162.00	Marlaceous clay, gray, hard, with a few plant relicts and xylite.
30	162.00-163.50	Lignite blackish, compact, with plant relicts and dull.
31	163.50-164.50	Lignite with the same characteristics of the above sample.
32	164.50-165.20	Greyish clay, soft, with plant relicts and fossils.
33	165.20-166.20	Lignite with ferrous oxides, blackish, dull. hard, friable, compact with distinct stratification and fossils.
34	166.20-168.00	Clay of gray to green colour, hard, with restricted presence of fossils.
35	168.00-169.50	Clay with the same characteristics of the above sample.
36	169.50-170.00	Lignite with fossils, blackish, hard, dull with distinct stratification and plant relicts.
37	170.00-170.50	Clay soft, of gray colour.
38	170.50-171.00	Lignite of brown to blackish colour, fossiliferous, with distinct stratification, dull, hard, rich in ferrous oxides. It smells sulphur.
39a	171.00-174.00	Clay soft, rich in organics, of gray colour, fossiliferrous.
39b	171.00-174.00	Clay with the same characteristics of the above sample without the presence of the organics.
40a	174.00-176.00	Marlaceous clay, hard, of gray colour, with xylite, fossiliferrous with high quartzy sand fraction.
40b	174.00-176.00	Clay with the same characteristics of the above sample darker because of the presence of the organics.
41	176.00-177.20	Lignite compact, dull occasionally lustrous parts, hard and friable, of brown to blackish colour. Distinct is the presence plant relicts, ferrous oxides.

42	177.20-177.70	Lignite soft, black, dull without plant relicts and stratification. Sample rich in clay and fossils.
43	177.70-179.00	Lignite hard and friable, compact without stratification, of brownish to blackish colour, rich in calcite and ferrous oxides.
44	179.00-180.00	Lignite with the same characteristics of the above sample.
45	180.00-181.20	Lignite soft, black, rich in pyrite and lustrous lenses. The general appearance is dull though. Distinct is the presence of plant relicts.
46	181.20-183.00	Lignite compact, hard and friable, dull with occasionally lustrous lenses and stratification of brownish to blackish colour.
47	183.00-184.00	Lignite with the same characteristics of the above sample.
48	184.00-185.00	Lignite soft, with restricted stratification, dull with lustrous lenses, of brown to blackish colour. Distinct is the presence of plant relicts. Sample rich in clay.
49	185.00-185.60	Gradual transition from lignite hard and friable, of brownish to blackish colour with stratification and presence of plant relicts fossils, ferrous oxides and pyrite to clay hard, of greyish colour, rich in humic matter
50	185.60-187.30	Clay hard, fossiliferous, of greyish colour, rich in humic matter and pyrite with the presence of quartzy sand fraction.
51	187.30-187.70	Clay with the same characteristics of the above sample, but with distinct presence of xylite.
52	187.70-188.00	Lignite soft, black, dull with lustrous lenses, pyrite and calcite. Stratification is distinct, plant relicts and fossils.
53	188.00-189.00	Gradual transition from fossiliferous clay, rich in humic material and plant relicts, pyrite, with high proportion of quartzy sand fraction to lignite hard and friable, of brownish to blackish colour, dull, compact rich in pyrite and ferrous oxides.
54	189.00-190.70	Gradual transition from the above lignite to fossiliferous clay hard, with distinct stratification, of greyish colour, rich in xylite
55	190.70-193.00	Clay of greyish colour, hard, fossiliferous with xylite.
56	193.00-194.00	Lignite hard, of brownish to blackish, rich in ferrous oxides and fossils, plant relicts, compact, dull, hard and friable.
57	194.00-195.00	Gray marlaceous clay hard, with fossils and xylite, of medium hardness.
58	195.00-195.30	Lignite of blackish colour, rich in clay, soft with stratification, rich in pyrite, quartz, with restricted presence of fossils.
59	195.30-195.50	Lignite soft, black with distinct stratification, dull, rich in argillaceous matter.
60	195.50-196.70	Lignite compact, hard and friable, of brown to black colour, dull, fossiliferous with restricted presence of ferrous oxides.
61	201.30-202.50	Lignite dull, with lustrous lences, hard and friable, of blackish colour, with stratification and rich in plant relicts.
62a	204.00-205.00	Gray clay with high proportion of quartzy sand fraction.
62b	204.00-205.00	Gradual transition of quartzy sand to clay of gray colour.

		rich in humic matter.
63	205.00-205.30	Black lignite, dull, with medium hardness, compact, rich in pyrite.
64	206.60-207.00	Gray clay, soft, rich in humic matter and ferrous oxides.
65	207.00-208.00	Quartzy sand with xylite and plants relicts.
66	213.00-213.20	Sandy clay with xylite.
67	213.20-214.30	Lignite hard and friable, dull, compact, of blackish colour, rich in ferrous oxides and fossils.
68	214.30-216.00	Dark gray clay, hard, rich in humic matter, plant relicts and xylite.
69	216.00-219.00	Lignite hard and friable, dull, compact, rich in ferrous oxides.
70	219.00-221.00	Lignite black, soft, compact with pyrite and ferrous oxides.
71	221.00-222.00	Lignite brown to black with plant relicts, ferrous oxides, compact, dull, hard and friable.
72	222.00-223.00	Lignite with the same characteristics of the above sample, but with lustrous lenses and rich in pyrite.
73	223.00-224.30	Greyish clay, dull, soft, rich in humic material.
74	225.00-228.00	Clay with the same characteristics of the above sample.
75	231.00-232.00	Lignite brown to black, with plant relicts, ferrous oxides, compact, dull, hard and friable.
76	232.00-233.00	Lignite black, soft, compact, with pyrite and ferrous oxides.
77	234.00-235.00	Sandy clay rich in humic material and pyrite.
78	235.00-236.00	Lignite of brown to black colour, with plant relicts, pyrite, ferrous oxides, compact, dull, hard and friable.

Nachwort zu den Artikeln von Antoniadis & Lampropoulou:

von Hans-Joachim Gregor

In Absprache mit meinem alten Kollegen Prodromos Antoniadis werden hier erste Ergebnisse von Beprobungen vorgelegt,die u.a. auch makropaläontologische Reste beinhalten. Eine Auswertung dieser Befunde wird etwas später erfolgen,wobei die Gastropoden von Kollegen Geissert übernommen werden, die Früchte und Samen von unserem Kollegen Evangelos Velitzelos und mir selbst. Wir haben ja schon mehrfach mit griechischen Braunkohlen zu tun gehabt (vgl. Documenta naturae No.28,29,67,74,78) und werden hier weitergehende Vergleiche anwenden, z.B. mit den Gebieten von Megalopolis,Ptolemais usw.
Wie bereits angedeutet werden kann,sind in den einzelnen Proben durchaus Reste zu finden,die interpretiert werden können und die eine Rekonstruktion der ehemaligen Verhältnisse im griechischen Großraum zulassen,wobei spezielles Gewicht auf das Plio/Pleistozän gelegt wird.
Für Interessenten mediterraner Floren mit ihrer Palökologie etc. möge hier noch erwähnt werden,daß eine größere Arbeit über alle neogenen Makrofloren Griechenlands (Gregor & Velitzelos) in Vorbereitung ist ,dies im Zusammenhang mit allen zirkummediterranen Gebieten (Gregor).