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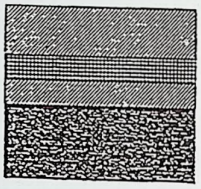
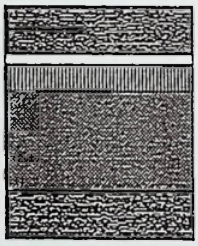
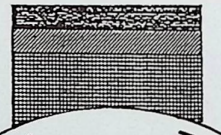


Die Braunkohlen-Lagerstätte



Amynteon

bei Kozani in NW-Griechenland



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Zum Fossilinhalt der Braunkohlen - Lagerstätte Amynteon bei Kozani in NW-Griechenland

von

P.A. Antoniadis & H.-J. Gregor

Summary

In the present paper diaspores (fruits and seeds) and other fossils are determined and interpreted, which were isolated from the intermediate sediments of the lignite seams of Amyndeon. The sediments are mostly clays and humic clays. The samples were taken from a representative borehole drilling in the main lignite deposit of Amyndeon and washed out with peroxide. The studied plant material allows a reconstruction of the environmental conditions and vegetation of the time of the lignites:
Water plants: *Ceratophyllum, Potamogeton, Najas, Stratiotes,* Characeae, *Trapa, Nymphaea*
Riverbank area: Cyperaceae, *Ranunculus,* Umbelliferae, *Proserpinaca*, *Typha, Scirpus*
Swamp*: Myrica, Decodon, Epipremnites*
Riparian forest: *Sambucus, Rubus*
The flora is dominated by water and reed plants and shows a bottomland area, which is typical for Upper Neogene (Pliocene) deposits in Europe. The climate can be determined as warm-temperate and humid (Cfa sensu KÖEPPEN), but passing into a somewhat cooler Cfb-climate.
In comparison to the Apophysi lignite the conditions of Amyndeon (see vol.1)seem to be poorer.

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Zusammenfassung

Es werden erste lithologisch-sedimentologische und paläobotanische Untersuchungen aus dem Gebiet von Amynteon bei Kozani in NW-Griechenland (Makedonien) vorgestellt. Die Daten stammen von einer repräsentativen Bohrung aus der Hauptlagerstätte und umfaßt mehr als 100 m. Die pflanzenführenden Schichten waren in diversen Horizonten der mineralreichen Braunkohlen und ihrer Begleitsedimente (Tone) zu finden. Die Frucht- und Samenflora gestattet mit ihrem Reichtum an Wasser-, Ried, Ufer- und Sumpfpflanzen eine Rekonstruktion der damaligen Bedingungen, wobei ausgedehnte Wasserflächen (Seen) mit sumpfigen Flächen (Röhricht,Moor) wechseln. Das Alter kann mit Oberes Neogen bzw. Pliozän bezeichnet werden. Das Klima war ein typische Cfa-Klima (sensu KÖEPPEN), aber wohl schon im Übergang zu etwas gemäßigteren Bedingungen (Cfb).

1. Introduction

The present paper is based on the geological data of a representative borehole drilled in the Amynteon main lignite deposit. It is already prepared and in print another paper where the geological data of a small deposit in the area of Apofysi-Amynteon are studied. The "Apofysi's" lignite deposit is an elongation of the main Amynteon lignite deposit. These two papers consist a complete picture of the area where the Amyndeon lignite deposit lies.

The latest most important work in the area was written by K., Koukouzas et. al. (1979).

The authors of this paper are grateful to Mr. Goumas Director of the research department of P.C.C. and to the geologists, Mr. Kyriakidis and Mr Kalaytzopoulos For the help that offered us during the sampling procedure.

The total thickness of the lignite seams is more than 40 m. A detailed borehole description can be found in the paper of Antoniadis et al. (1995) Documenta naturae 96:35-43.

The present paper consists of a small reference on the geological conditions of the deposit and a detailed interpretation of the palaebotanical data in order to assess the paleoecology, the paleoclimate and the phytostromatography of the deposit.

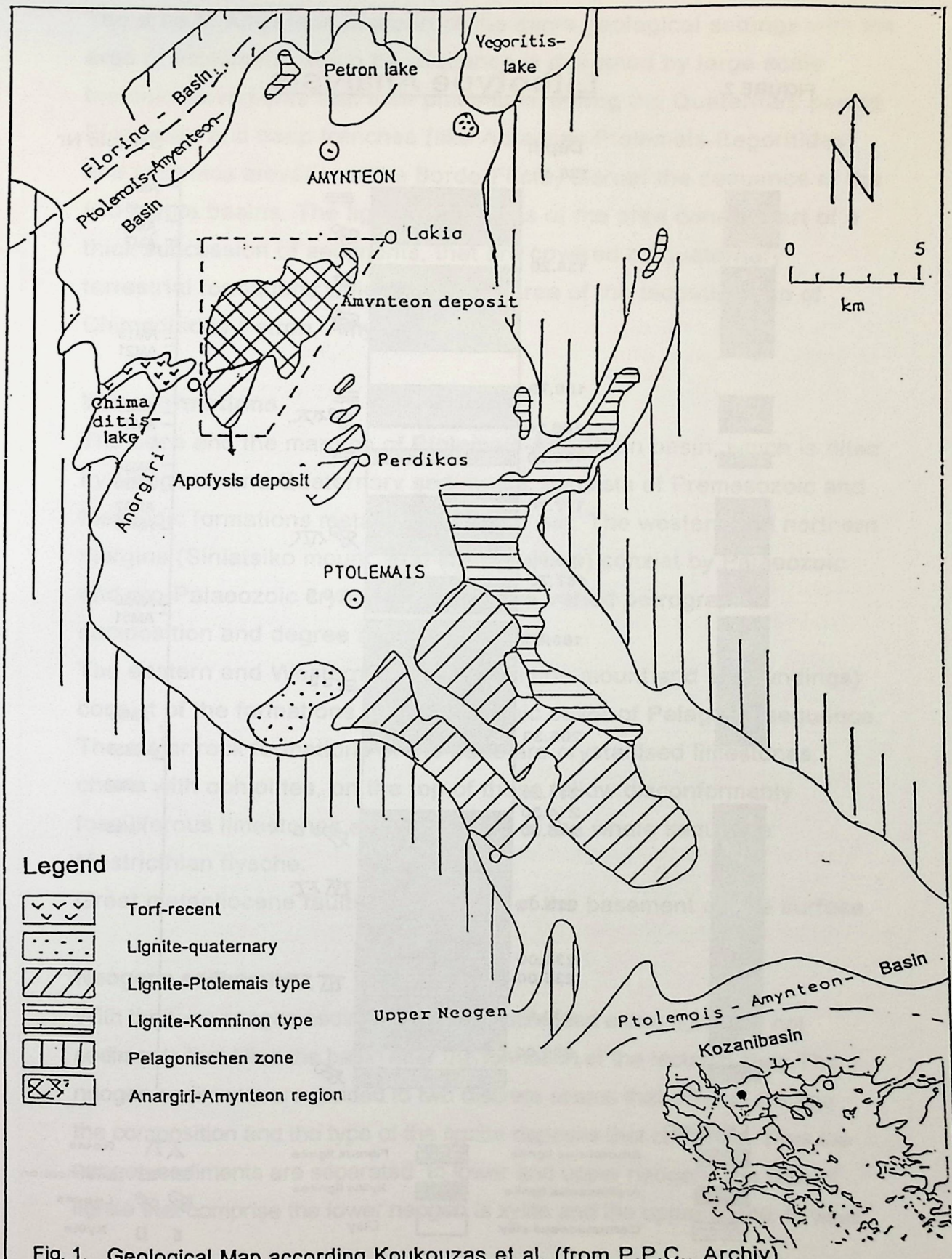
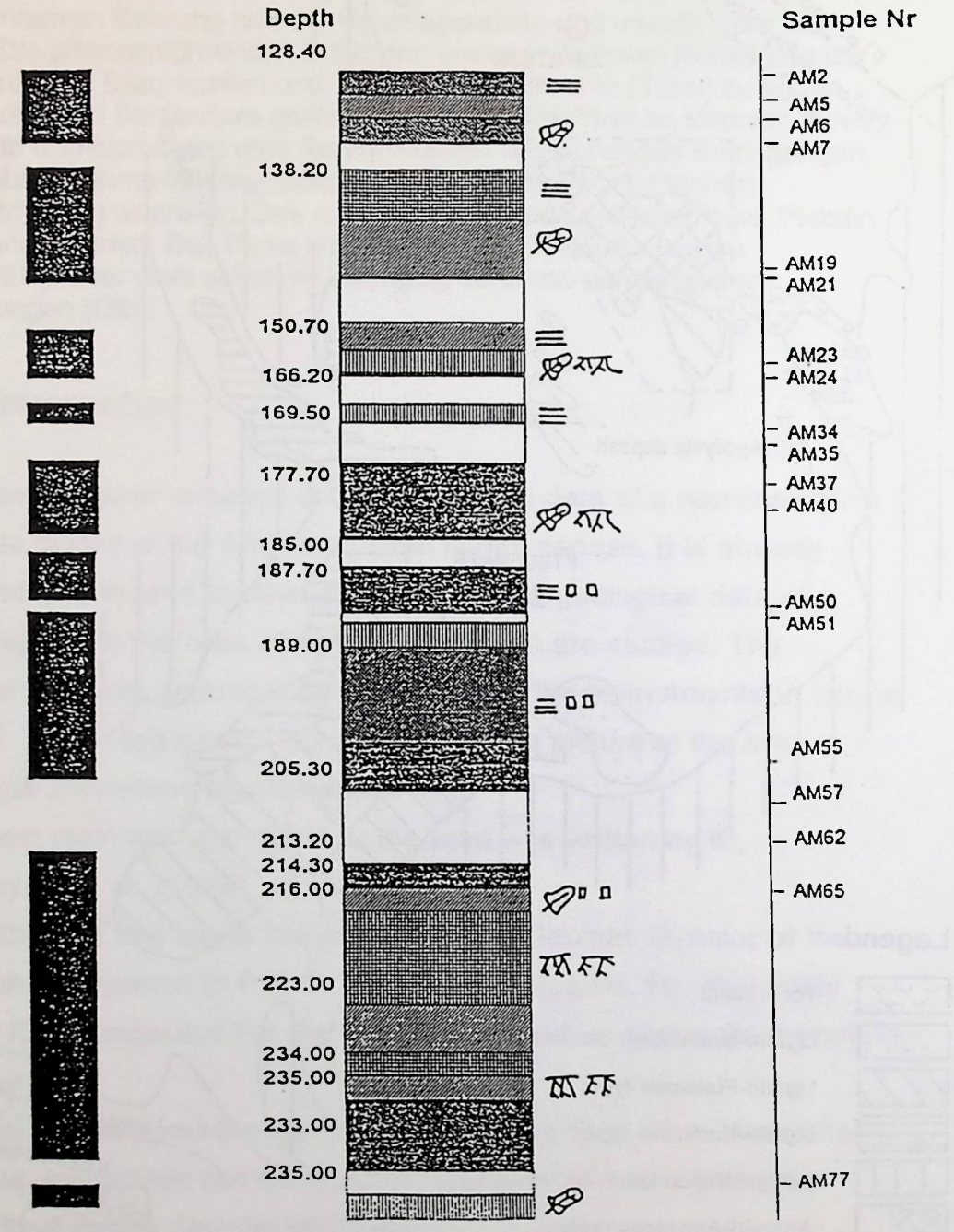


Fig. 1. Geological Map according Koukouzas et al. (from P.P.C., Archiv).

FIGURE 2.

Lithotype Analysis



2. Geology

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.

Great 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.

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.

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 Pleistocene 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.

TABLE 1/A

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 black 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-black colour.
5b	132.00-133.50	Green-gray clay, occasionally fossiliferous, rich in quartz 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 quartz sand. Medium hardness, gray.
12	139.70-140.00	Lignite of black color, hard, friable, with intercalation's of quartz clay, fossiliferous, rich in plant relicts.
13	140.00-141.00	Lignite, friable, fossiliferous, of black 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 black color.
16	143.50-144.00	Alternation of hard, gray clay with black lignite, compact, dull, with argillaceous intercalation's.
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, black, 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.

TABLE 1/B

20	147.20-147.70	Lignite, black, 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 black 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 quartz 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 black color, 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 black, 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, black, 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, black, 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 black color, fossiliferous, with distinct stratification, dull, hard, rich in ferrous oxides. It smells sulphur.
39a	171.00-174.00	Clay soft, rich in organic matter, of gray colour, fossiliferrous.
39b	171.00-174.00	Clay with the same characteristics of the above sample without the presence of the organic matter.
40a	174.00-176.00	Marlaceous clay, hard, of gray colour, with xylite, fossiliferrous with high quartz sand fraction.
40b	174.00-176.00	Clay with the same characteristics of the above sample darker because of the presence of the organic matter.
41	176.00-177.20	Lignite compact, dull occasionally lustrous parts, hard and friable, of brown to black color. Distinct is the

TABLE 1/C

		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 black color, 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 black color.
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 black color. 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 black color 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 quartz 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 quartz sand fraction to lignite hard and friable, of brownish to black color, 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 black, 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 black color, 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.

TABLE 1/D

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 lenses, hard and friable, of black color, with stratification and rich in plant relicts.
62a	204.00-205.00	Gray clay with high proportion of quartz sand fraction.
62b	204.00-205.00	Gradual transition of quartz 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	Quartz 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 black color, 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.

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.

3. Profile and Sample description

Evaluation analysis

In the following chapter the plant remnants of the samples' AM 2-77 were studied. It is important to confirm that the study of the samples was carried out using the typical procedure of data analysis without paying attention to other factors that can influence the evaluation of the data.

3.1. Paleoecology

All the types of fossils of the samples 2-77 show an definitive trend to represent a type of vegetation that originates from an open marsh and a reedzone environment. Any other impact corresponds to the same conditions. The most important recognised fossils are :

Water plants : *Ceratophyllum, Potamogeton, Najas, Stratiotes,* Characeae, *Trapa, Nymphaea.*

Riverbank area: Cyperaceae, *Ranunculus*, Umbelliferae, *Proserpinaca, Typha, Scirpus.*

Swamp: *Myrica, Decodon, Epipremnites,*

Riparian forest: *Sambucus, Rubus*

Table 2. Identified plant fossils per sample

Age	Sample number	Diaspores	Other remains
Upper Plio-cene	AM2	Chenopodiaceae *Ranunculus sp.* *Scirpus sp.* *Potamogeton sp.*	Pyrite Wood Gagate
Upper	AM5	*Polygonum sp. Rezent*	
	AM6,7	*Decodon globosus* Chenopodiaceae *Sambucus pulchella* *Nymphaea sp.* *Typha sp.* *Rumex sp. Rezent*	Wood Fusinite
	AM19	Chenopodiaceae rezent *Cenococcum geophilum*	Wood Pyrite
	AM21		Fusinite, Coprolith, Wood
	AM23		Gastropoda, Fusinite
	AM24	Characeae(cf. *Tectochara meriani)*	Wood
Upper ?	AM26	*Polygonum sp.* *Potamogeton sp.* Caryophyllacea Chenopodiaceae with seedling - rez. *Nymphaea sp.*	Coleoptera
	AM34	*Sambucus pulchella*	
	AM35	*Potamogeton piestanensis* *Ceratophyllum sp.*	
	AM37	Chenopodiaceae-rez. *Typha sp.* *Trapa sp. -hooks*	Coleoptera
Upper ?	AM40	*Najas sp.* *Hypericum sp.* *Stratiotes aff. -tuberculatus* *Trapa sp. -hooks*	Fishbones
	AM50	*Decodon globosus*	Teeth of Cyprinids
	AM51	Cyperaceae	resent pollution of Gastropodes
	AM55		
	AM57	*Najas sp.* *Stratiotes aff. tuberculatus*	
Middle ?	AM62	*Ceratophyllum sp.* *Potamogeton piestanensis* *Potamogeton sp.* Cyperaceae *Rubus sp.* Umbelliferae *Typha sp.* *Decodon globosus*	wood
Middle ? Pliocene	AM65	*Proserpinaca reticulata* *Ceratophyllum sp.* *Najas sp.* *Epipremnites reniculus* *Potamogeton piestanensis* *Sanbucus pulchella* *Decodon globosus* *Rubus sp.* *Myrica sp.*	
	AM77	*Decodon globosus*	Fusinite

Table 2: Identified plant fossils per sample

The overall picture shows an accumulation of all the types of vegetation, which are typical to warm climates, and can be found all over the European Neogene formations (Cfa sensu KOEPPEN).
The paleoenvironmental reconstruction of the mesophytic forest and the Aue forest is impossible because of lack of data.
According the data of other similar Greek lignite deposits and of areas close to the deposit, that is studied in the present paper we can infer that we are dealing with plants of a soft to hard woody Aue forest, where the most important plants were *Ulmus, Zerkova, Quercus, Acer, Glyptostrobus* etc.

3.2. Palaeoclimate

The water plants give poor climatic data. Nevertheless comparing the data to other similar European deposits we can infer that the climate was characterised by warm summers. The presence of the plant *Nymphaea* in connection to the presence of *Myrica*, which thrives under subtropical conditions, indicates a climate which is characteristic of all Neogene deposits in Middle Europe. Such a reconstruction of a Cfa-climate is fully accepted by all authors, working with megafloras.

3.3. Phytostratigraphy

The plant fossils found in the samples of the present paper cannot be used to phytostromatography. This type of vegetation can give valuable data only in ecology and in facies analysis.
The few types, that can be used are:

Potamogeton wiesaensis-Upper - Pliocene in Czechoslovakia
Stratiotes cf. *tuberculatus* - European Pliocene
Decodon globosus - Neogene
Epipremnites reniculus - European Pliocene
Sambucus pulchella - European Pliocene

Table 3: Systematic list of plant fossils with abundance

Class	Family	Taxon/species	Abundance
Charophyta	Characeae	*cf.Tectochara meriani*	oo
Angiospermae			
Dicotyledoneae			
	Myricaceae	*Myrica sp.*	i
	Polygonaceae	*Polygonum sp.*	l
		Rumex sp.	l
	Caryophyllaceae	gen.indet.	l
	Chenopodiaceae	gen.indet.	oo
	Ranunculaceae	*Ranunculus sp.*	l
	Nymphaeaceae	*Nymphaea cf.alba*	o
	Ceratophyllaceae	*Ceratophyllum sp.*	oo
	Guttiferae	*Hypericum sp.*	l
	Rosaceae	*Rubus sp.*	o
	Lythraceae	*Decodon globosus*	oo
	Trapaceae	*Trapa sp.*	0
	Haloragaceae	*Proserpinaca reticulata*	l
	Umbelliferae	gen.indet.	l
	Caprifoliaceae	*Sambucus pulchella*	o
Monocotyledo-neae			
	Hydrocharitaceae	*Stratiotes cf.tuberculatus*	oo
	Najadaceae	*Najas sp.*	o
	Potamogetona-ceae	*Potamogeton piestanensis*	oo
		Potamogeton sp.	oo
	Cyperaceae	gen.indet.	oo
		Scirpus sp.	l
	Typhaceae	*Typha sp.*	oo
	Araceae	*Epipremnites reniculus*	oo

(l=1 specimen, o=2-10,oo=11-more specimen)

All other types are valuable only in facies analysis.
According the available data the deposition took place in Pliocene, that starts according the profile from the samples AM6,7 and stops most possibly in the horizon were the sample AM 65 was taken.
A most definite study which concerns the age, the ecology and the climate of the deposit can be found in the paper of Günther & Gregor, which is the procedure of writing up European floras and which concerns the study of diaspore fossils. Generally speaking the vegetation of Amynteon corresponds to the climatic conditions of the Upper to Middle Pliocene.

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Special Remarks for greek writing:
Sometimes the name „Amynteon"" is written Amyndeon, similar Apofysi is written Apophysi.