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GEOLOGICAL EVOLUTION – STRATIGRAPHY OF FLORINA, PTOLEMAIDA, KOZANI AND SARADAPORO GRABEN

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Abstract

The purpose of this research is to comprehend the geological and stratigraphical evolution of Florina, Ptolemaida, Kozani and Sarandaporo graben. This graben extends North of the Greek borders and is more than 150 Km long.
The activity of big and profound faults of NW-SE direction, in NW Macedonia, after the end of the Alpine orogenesis cycle and during the Early Miocene was related to the formations' deposition.
A large number of samples were collected from drill cores for the examination of palynology, paleoflora, fossils, and diatoms in order to determine the formations' sequence and age.
The basement and the borders of the depression, belong to the Pelagonian geotectonic zone. The deposition of the ***Early Neogene's series*** *is following. During the Late Pliocene the previous series, is developing into a lacustrine-marshland system, resulting to the deposition of* ***Late Neogene's series*** *formations. In the Quartenary the following formations are deposited:* ***Proastion formation, Perdika formation, terrestrial, fluvial-terrestrial formation, recent formation.***
Four (4) phases of lignitogenesis have been specified, mainly in the Ptolemaida – Amynteo basin.
In this graben they have been deposited the most important lignite deposits of Greece.
Key words: *lignite deposits, NW Macedonia.*

Περίληψη

Μετά το πέρας του Αλπικού ορογενετικού κύκλου και κατά τη διάρκεια του Κατώτερου Μειόκαινου, στην περιοχή της ΒΔ Μακεδονίας –όπως και σε όλο τον Ελλαδικό χώρο– αρχίζει ένας έντονος ρηγματογόνος τεκτονισμός. Αποτέλεσμα αυτού και εξαιτίας της δράσης μεγάλων και βαθιών ρηγμάτων, κύριας διεύθυνσης ΒΔ-ΝΑ, δημιουργείται η Τάφρος Φλώρινας, Πτολεμαΐδας - Αμυνταίου, Κοζάνης-Σερβίων και Νοτιότερα η λεκάνη Σαρανταπόρου. Η τεκτονική αυτή Τάφρος επεκτείνεται πέραν των Ελ-

ληνικών συνόρων προς Βορρά και έχει μήκος μεγαλύτερο των 150 Km. Ένα μεγάλο πλήθος δειγμάτων για την εξέταση παλαιοχλωρίδας, διατόμων, παλυνολογικών εξετάσεων και απολιθωμάτων, με σκοπό τον ακριβή προσδιορισμό της ηλικίας των διαφόρων σχηματισμών, λήφθηκε από τους πυρήνες των γεωτρήσεων.
Το υπόβαθρο και τα περιθώρια του βυθίσματος αυτού, γεωτεκτονικά ανήκουν στην Πελαγονική ζώνη. Ακολουθεί η απόθεση της κατώτερης Νεογενούς σειράς. Κατά τη διάρκεια του ανώτερου Πλειοκαίνου, η παραπάνω σειρά εξελίσσεται σε ένα λιμναίο - ελώδες σύστημα, με αποτέλεσμα την απόθεση των σχηματισμών της ανώτερης Νεογενούς σειράς. Στο Τεταρτογενές αποτίθενται οι παρακάτω σχηματισμοί: Σχηματισμός Προαστείου, Σχηματισμός Περδίκα, Χερσαίοι, Ποταμό - χερσαίοι σχηματισμοί, πρόσφατοι σχηματισμοί.
Τέσσερις (4) φάσεις λιγνιτογένεσης έχουν παρατηρηθεί, κύρια στην λεκάνη Πτολεμαΐδας – Αμυνταίου.
Σε αυτή την τεκτονική τάφρο έχουν εντοπισθεί τα κυριότερα Ελληνικά λιγνιτικά κοιτάσματα.
Λέξεις κλειδιά: *λιγνιτικά κοιτάσματα, ΒΔ. Μακεδονία.*

1. Introduction

This work is the result of a long-lasting research (more than 55 years) carried out by several colleagues who worked in the Geological Institute of Greece, (previously called Geological Service, Institute of Geological Research of Subsoil, National Institute of Geological and Mineral Exploration, Institute of Geological and Mineral Exploration), an Institute which has always been the main center for research in the Energy Resources in Greece.

Some hundred thousands of meters of drill cores were studied and were evaluated, for better determination of the formations sequence and age as well as the tectonic activity in the area. For that purpose a large number of samples were collected from the drill cores for the examination of palynology, paleoflora, fossils, and diatoms.

2. Development – Geological evolution of Graben

After the end of the Alpine orogenesis cycle and during the Early Miocene, an intense tectonic faulting begins, in NW Macedonia, as well as allover Greece. The activity of big and profound faults of NW-SE direction, results to the development of the Florina, Ptolemaida- Amynteo, Kozani– Servia and Sarandaporo graben. This Graben extends North of the Greek borders in F.Y.R.O.M. (Monastiri area), and is more than 150 Km long (Fig. 1).

In this newly created graben some areas, such as Kozani, Xino Nero - Klidi and others, (Fig. 2) are preexistent elevations, which under the influence of faults (NE–SW) vertical to the previous, behave as elevations, or as constant and durable masses in the synizesis, in reference to the other areas of the graben. These elevations separated the graben in many basins (Florina, Amynteo, Ptolemaida, Kozani and Sarandaporo), which some times were autonomous and other times communicated, thus having common geological development. In both cases, we observe during the Neocene and Quaternary, the same or homologous formations along the graben.

The basement and the borders of the depression, belong to the Pelagonian geotectonic zone (Fig. 3). These formations mainly occupy the east and south–southwest borders of the graben. The west and northeast borders consist of by the Paleozoic formations of the crystalline basement of the Pelagonian mass.

During the Late Miocene-Early Pliocene, the graben and mainly the basins in it begin to fill with terrestrial, fluvial, torrential, lacustrine and marshy deposits. Thus we have the deposition of the **Early Neogene's series** (Figs 4, 5), in which we find the large lignite deposits of "xylitic type".

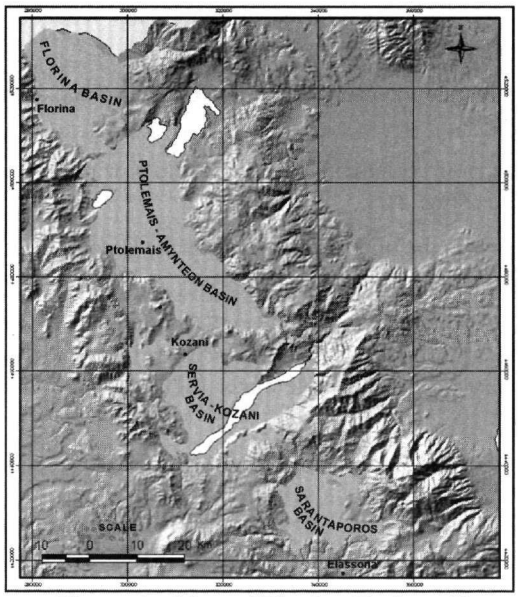

Figure 1 - Map of Florina-Ptolemaida Kozani and Sarantaporo basins

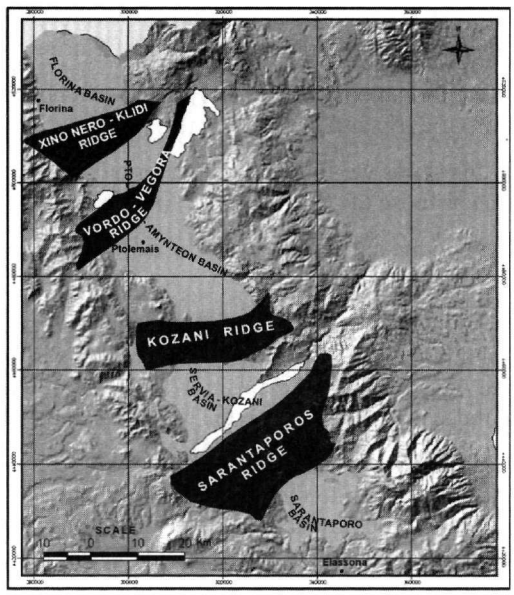

Figure 2 - Map of Graben with ridges

The Early Neogene's series extends in the entire graben. Its main volume is developed in the east borders of the Ptolemaida– Amynteo basin where it exceeds 600m of thickness, in Florina basin, in the south of Kozani-Servia basin, as well as in Sarandaporo basin. As we see in Fig. 6, the lignite bearing formation of the Early Neocene is developing in the east borders of the graben, with the known lignite deposits of Florina, Komnina, Anatoliko, Lava etc. where its thickness declines gradually to the west.

During the Late Pliocene the series that was described earlier, is developing into a lacustrine-marshland system, resulting to the deposition of **Late Neogene's series** formations (Figs 4, 5).

Due to the tectonic activity and the paleogeografical and paleogeomorphological conditions that prevailed this period, this system occupies the entire Ptolemaida – Amynteo basin,

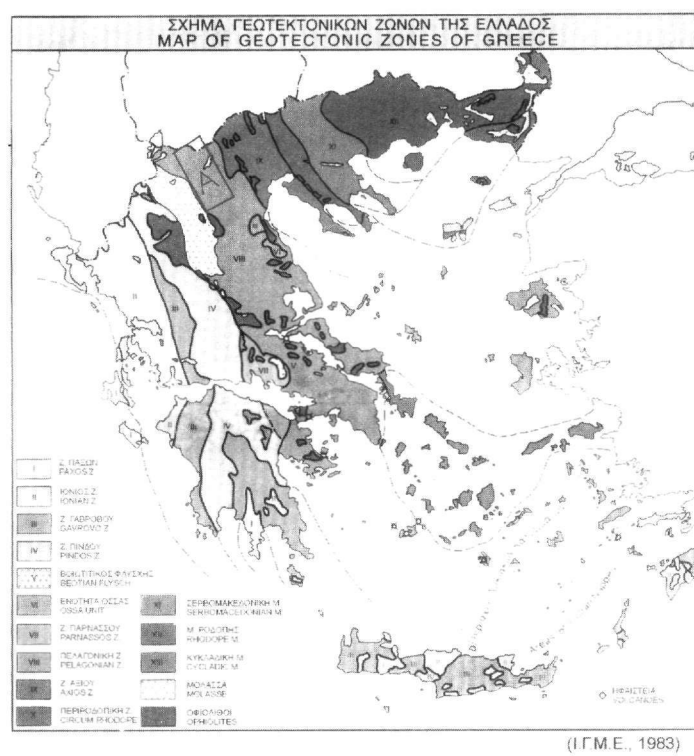

Figure 3 - The position of the Graben ("A" region) in relation to the Greek geotectonic zones

with the exception of the east-northeast section, the Kozani-Servia basin and finally reaches in small endings the southeast section of Florina basin (Fig. 7).

These formations are lake, lacustrine-swampy, and marshy deposits. Their age is determined at the limit of Early and Late Pliocene.

In this series we find the known large lignite deposits of Ptolemaida-Amynteo and Kozani basins, such as those of "South Field", Amynteo, Petrana etc. (Fig. 8).

The houdite and hydromagnesite deposits are locating in the upper formations of the Kozani basin.

The thickest parts of this series, about 500m, were observed in the central and west section of the Ptolemaida-Amynteo basin (Proastion deposit). Also in this area the thickest lignite seam (385 m) and lignite bed (60 m) were observed. This is the result of the ideal conditions concerning the relation of synizesis and deposition. The depositional rate of the vegetable mater followed the rhythm of the synizesis leading to the big Ptolemaida-Amynteo deposits.

A normal transition from the underlying formations of the Early Neogene's series (Late Miocene-Early Pliocene), to the overlying formations of the Late Neogene's series (Early-Late Pliocene) is observed. The absence of these formations in Florina, Sarandaporo basins and the east-northeast section of the Ptolemaida-Amynteo basin, is due to the tectonic activity of this period, which resulted to the rise of these sections of the graben.

After the deposition of the Neogene's formations, begins the deposition of **Proastion formation** (Figs 4, 5) during the Early-Middle Pleistocene (Villafrangian). They are fluvial, fluvial - torrential deposits.

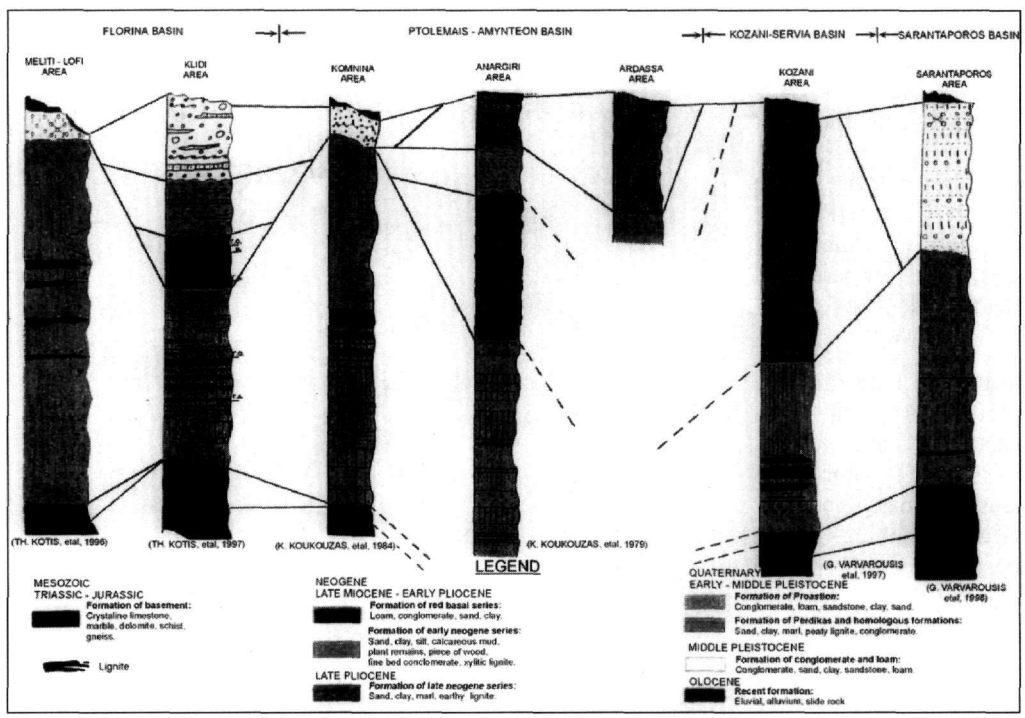

Figure 4 - Stratigraphic correlation between lignite basins of Florina, Ptolemaida – Amynteon, Kozani and Sarantaporo

This formation is limited mainly in the Ptolemaida– Amynteo basin and the southeast section of the Florina basin (Klidi area) (Fig. 9). An unconformity with the underlying Neogene's formations is observed. The main volume of this formation, as well as its stratigraphy, is observed in the ho-

monymous area of Proastion.

After the deposition of the Proastion formation, a strong, fault tectonism, of northeast-southwest and east-west main direction is observed, because of which new smaller basins were created inside the preexistent ones, for example the Ardassa-Vegoritida and Anargyroi-Petron basins. At the same time elevations are formed, or these that already exist amount more. Generally this tectonism along with the preexisting one created the present morphology of the graben.

The deposition of **Perdika formation** follows (Figs 4, 5), mainly in the new basins that are formed within the Ptolemaida-Amynteo basin, after the tectonics that has already been described (Fig. 10). These are fluvial, fluvial- torrential and lacustrine-marshy deposits. A new phase of thick lignitogenesis, with small beds of lignite and thick intermediate wastes is observed. (Fig. 11).

During the Middle Pleistocene we have the deposition of one **terrestrial, fluvial-terrestrial formation** (Fig. 5). This formation is stretching in the southeast section of the Florina basin, in major part of the Sarandaporo basin, in the southeast borders of the Ptolemaida basin and around the Kozani- Servia basin. In most of Sarandaporo basin, this formation is corroding the Early Neocene series formations and acquires its major thickness (Fig. 12).

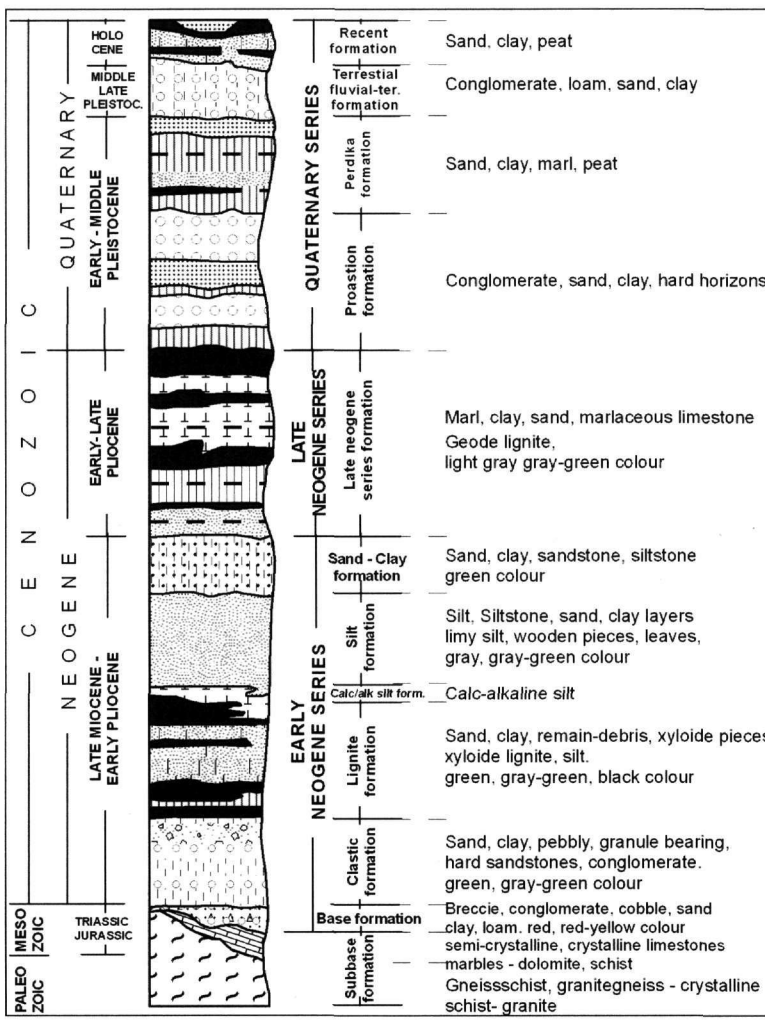

Figure 5 - Synthetic stratigraphic column of the Florina, Ptolemaida – Amynteon, Kozani, Sarantaporo Graben

On the surface we observed contemporary low thickness terrestrial depositions, like **eluvia mantles, alluvial depositions** and **alluvial fans**.

Likewise during the Holocene we have **deposition of peat** in the lakes Chimaditida, Zazari and Vegoritida, where we also observe the last phase of lignitogenesis (Fig. 13).

A schematic representation of the Kozani-Servia basin's paleogeographic evolution is given in Fig. 14, through the different geological periods. The evolution of the entire graben is about the same.

3. Geology – Stratigraphy of the Graben

The basement and the borders of the depression belong, as mentioned above, in the Pelagonian zone and consist of hemi-crystalline to crystalline Triassic-Jurassic limestones, marbles, dolomites and schists. In many places there are lenticular intercalations of phyllites, like in the elevation of Kozani. Also around the city of Kozani and in the west and south of the Kozani-Serbia basin, we observe Jurassic ophiolite rocks. The Pelagonian zone formations also consist of other rocks and occupy mainly the east and south-southwest borders of the graben. The west and northeast borders are composed by formations of the Paleozoic crystalline basement of the Pelagonian mass, and mainly consist, of gneissoschists, granitogneissous and crystalline schists. Similar rocks are also found on the borders of the Sarandaporo basin. We should also mention the known granites that can be observed on the west borders of the Florina basin.

During the Late Miocene-Early Pliocene, the tectonic fault and mostly the basins included in it, begin to fill with terrestrial, fluvial- torrential, fluvial, lacustrine-fluvial, lacustrine and marshy depositions. Thus indicates the deposition of the Early Neogene series (Figs 4, 5, 6). The series age is determined through the diatoms examination (E. Velitzelos), the paleobotany (Schneider and Velitzelos 1973, 1976, 1977) and the palynologic examination (Ioakeim and Vasileiou 1982, Ioakeim 1985), as Late Miocene (;)- Early Pliocene and is comprised, from bottom to top, by the following formations:

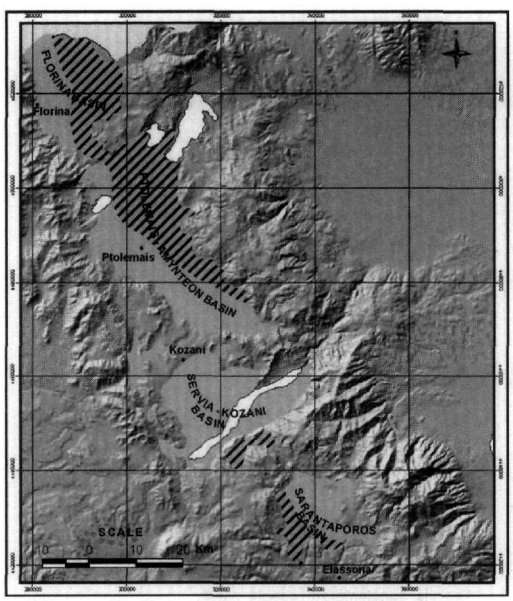

Figure 6 - Location map of lignite formation of late Neogene's series

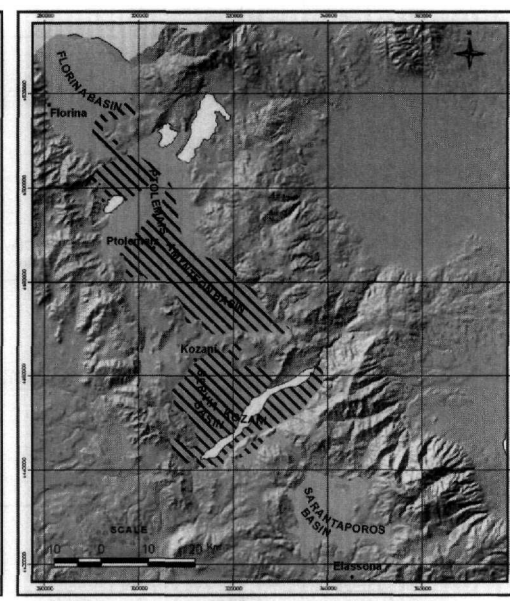

Figure 7 - Location map of late Neogene's

Initially we have the deposition of talus, terrestrial and fluvial- torrential sediments (**Base formation** – Fig. 6) which consist of breccias, whose elements are in proportion to the underlying or nearby basement rocks, conglomerate, disk-shaped stones with varied size elements, in alternation

with sands, clays and mud. The dominating color is red- red brown.

This formation fills and smoothes the irregular surface of the first graben basement. Because of this the formation's thickness varies from one place to the next and sometimes can vary from a certain minimum to several tens of meters. Indicatively we report, that the thickness in the Komnina area is 80m. The base formation expands all over the graben.

Stratigraphically fluvial deposits lie on the previous base formation (Fig. 5); they consist of fine to coarse sands sometimes clayey, and clays in some places sandy. There are interferences of pebbly and granule bearing layers, hard sandstone horizons, as well as conglomerate layers (**clastic formation**) (Fig. 5). Green and green-gray are the prevailing colors. Naturally, in every section of the fluvial system, we find the corresponding sediments.

The lacustrine- fluvial and marshy deposits (**lignite bearing formation**) (Fig. 5) overlying the previous formation, consist of sands, clays with plant remains, xylite pieces and lignite beds of "xylitic type", in alteration with silt and rarely marl. Green and green-gray are the prevailing colors. The biggest "xylitic type" lignite deposits are hosted in this formation, like those of Florina (Kotis *et al.* 1992, 1995, 1996, 1997), Komnina (Koukouzas *et al.* 1984), Lava etc.

This system develops in a clearly lacustrine environment and occupies almost entirely the graben. So, we have the deposition of the silts (**Silt formation**) (Figs 4, 5), with beds of sands and clays in some places. Frequently we observe interferences of calcareous silt - limy silt. In these sediments wood pieces, plant remains, leaves and mineral vivianite are observed. Gray and green-gray are the prevailing colors. On the top of the lignite-bearing stack lies a thin layer of calcareous silt with Ostracodes and operculum (**calc-alkaline silt formation**) is observed (Fig. 5).

This lacustrine system prevails mainly on the Sarandaporo basin, the south-southeast section of the Kozani-Servia basin and the east section of the Ptolemaida – Amynteo basin. On the west of this and the Florina basin, there is the prevalence of a fluvial – fluvial-lacustrine environment with the corresponding sediments. Instead of the silts it is finding fine to coarse sands, with interferences of clays and rarely silts.

Fluvial depositions, overlying the previous formations, consist of alternations of sands, clays with beds of sandstone and siltstone, (**sand-clay formation**) (Fig. 5). The prevailing color is green.

Afterwards and during the Late Pliocene, the previously mentioned lacustrine system is evolving into a lacustrine-marshy system resulting to the deposition of the Late Neogene's series formation (Figs 4, 5).

Due to the tectonic activity and the paleogeographical and paleogeomorphological conditions that prevailed this period, this system occupies the entire Ptolemaida – Amynteo basin, with the exception of the east-northeast section, the Kozani-Servia basin and finally reaches in small endings the southeast section of Florina basin (Fig. 7).

The sediments observed in the Late Neogene's series formation (Figs 4, 5) are marls, clays, sands, marly limestone and earthy lignite, alternated and combined. The prevailing colors are light gray and gray-green.

Fossils of gasteroides (Vetoulis 1956, Gramman 1960) such as *Theodoxus macedonicus* (Neritina), *Valvata piscinalis* etc., lamel gills (Gramman 1960), such as Unio sp. etc, Ostracods such as *Candona neglecta, Iliocypris gibba* e.t.c. and rodents (van de Weerd, 1979) are observed. Traces of paleoflora were specified and pollen was analysed (Ioakim, 1985). From these analyses the age of these formations is set at the limit of Early and Late Pliocene.

In this series the largest known lignite deposits of Ptolemaida-Amynteo and Kozani basins are found, such as these of "South Field" (Anastopoulos and Koukouzas 1972), Amynteo (Koukouzas *et al.* 1979), Perana (Anastopoulos and Brousoulis 1973), etc. (Fig. 8).

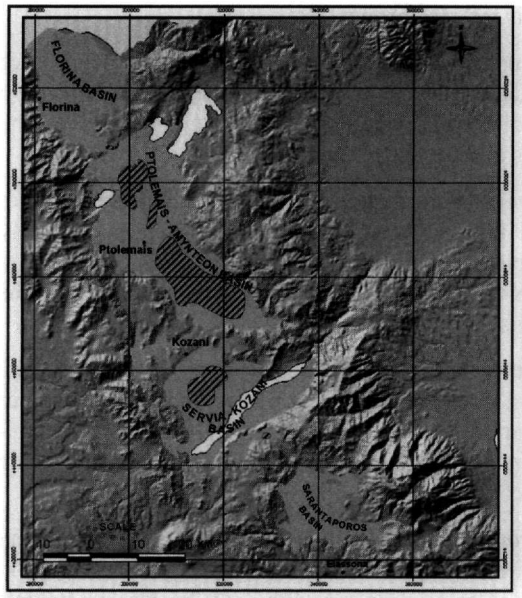

Figure 8 - Map of late Neogene's series deposits (geode lignite deposits)

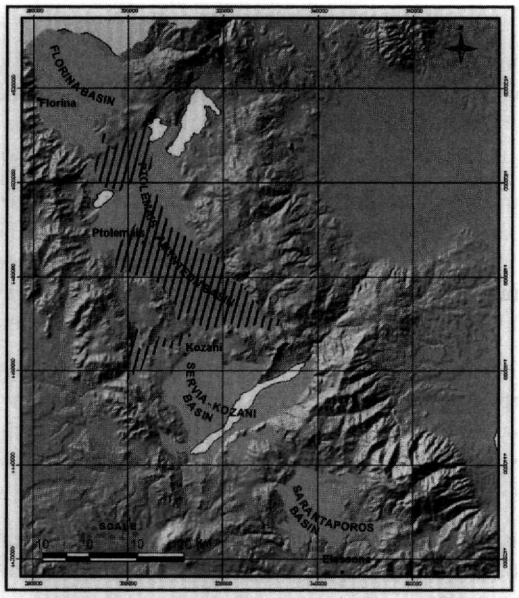

Figure 9 - Location map of Proastion formation

After the Neocene formations deposition, begins the **Proastion formation** deposition (Fig. 5), during the Early-Middle Pleistocene (Villafrangian). There are fluvial, fluvial-torrential depositions that consist of conglomerate, mixed with well-rounded stones of various sizes, with local alternations of sands and clays. These formations are characterised by cross bedding and hard horizons. The formation's maximum thickness is 150 m. During the research, no fossils have been found in the graben, except some Unio at some places. Fine beds of lignite or marshy formations have been observed locally; their extension is small and has no economic interest.

This formation is limited mainly in the Ptolemaida-Amynteo basin and in the southeast section of the Florina basin (Klidi area) (Fig. 9). It is in unconformity with the underlying Neogene formations. The site with the largest volume and presentation of the formation is found in the Proastion area, which actually gave it its name.

Later follows the deposition of **Perdika formation** (Fig. 5), mainly inside the Ptolemaida – Amynteo basin in the newly created sub basins of tectonic origin as previously mentioned (Fig. 10). These depositions are fluvial, fluvial-torrential, lacustrine and marshy. They consist of sands, clays, marls and beds of lignite.

The tectonic activity continued during the Perdika formation deposition, with extended movements, so thick layers of lignite are not observed. On the contrary, many fine beds of lignite with thick interferences of wastes are observed. That is why the lignite deposits of this period have no economic interest (Fig. 11). In the Ardassa area the formation reaches its top thickness at about 350m.

During the middle Pleistocene a terrestrial, fluvial-terrestrial formation is deposited (Fig. 5) and consists of conglomerate with various sized round stones and cobbles, of red loam beds, clays and sands. In some places hard horizons are observed. This formation is spread, as mentioned above, in the Florina basin, as well as in the Sarandaporo basin, where it acquires its maximum thickness (Fig. 12), in the southeast borders of the Ptolemaida – Amynteo basin and on the borders of the Kozani-Serbia basin.

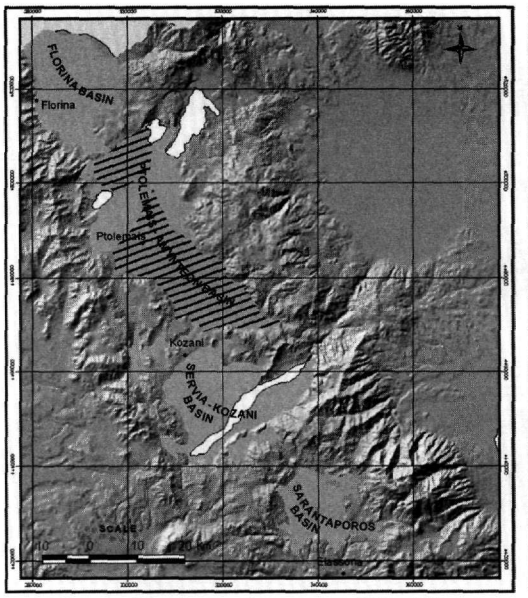

Figure 10 - Location map of Perdika formation

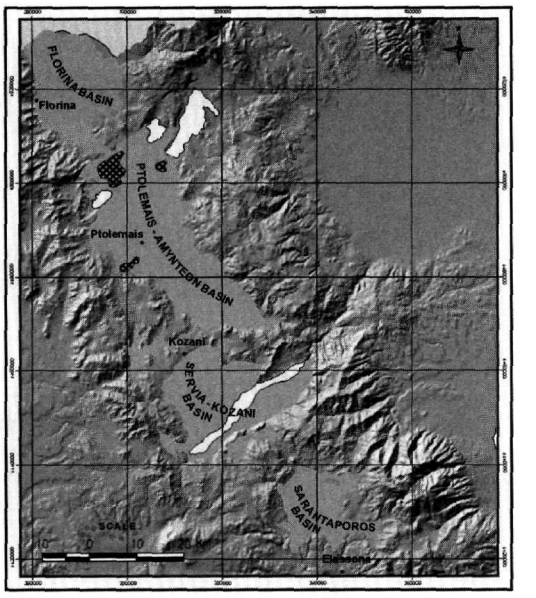

Figure 11 - Location map of lignite deposit in Perdika formation

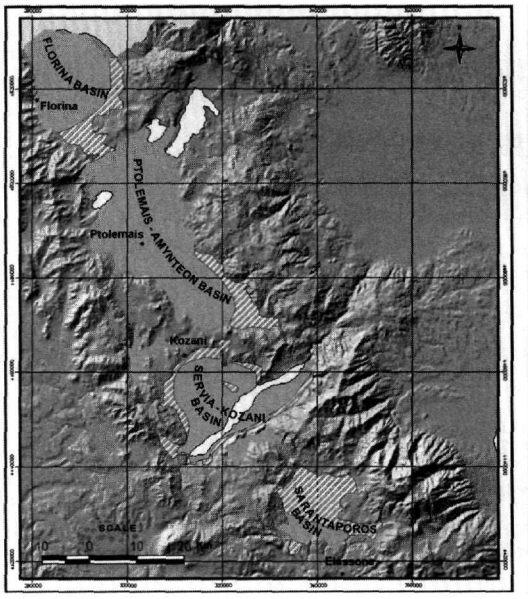

Figure 12 - Location map of Quaternary terrestrial deposit formation

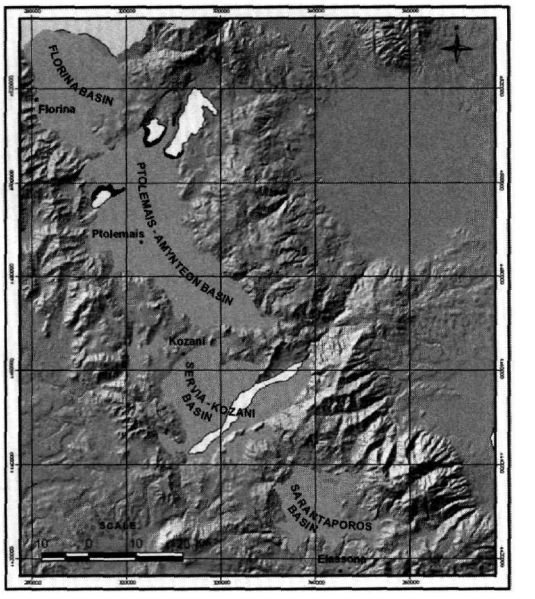

Figure 13 - Location map of recent peat

On the surface lie fine contemporary terrestrial depositions, such as eluvia mantles, alluvial deposits and alluvial fans.

We must also mention that during the Holocene peat is deposited in the remaining lakes Chimaditis, Zazari and Vegoritida, where the last phase of lignitogenesis can be observed (Fig. 13).

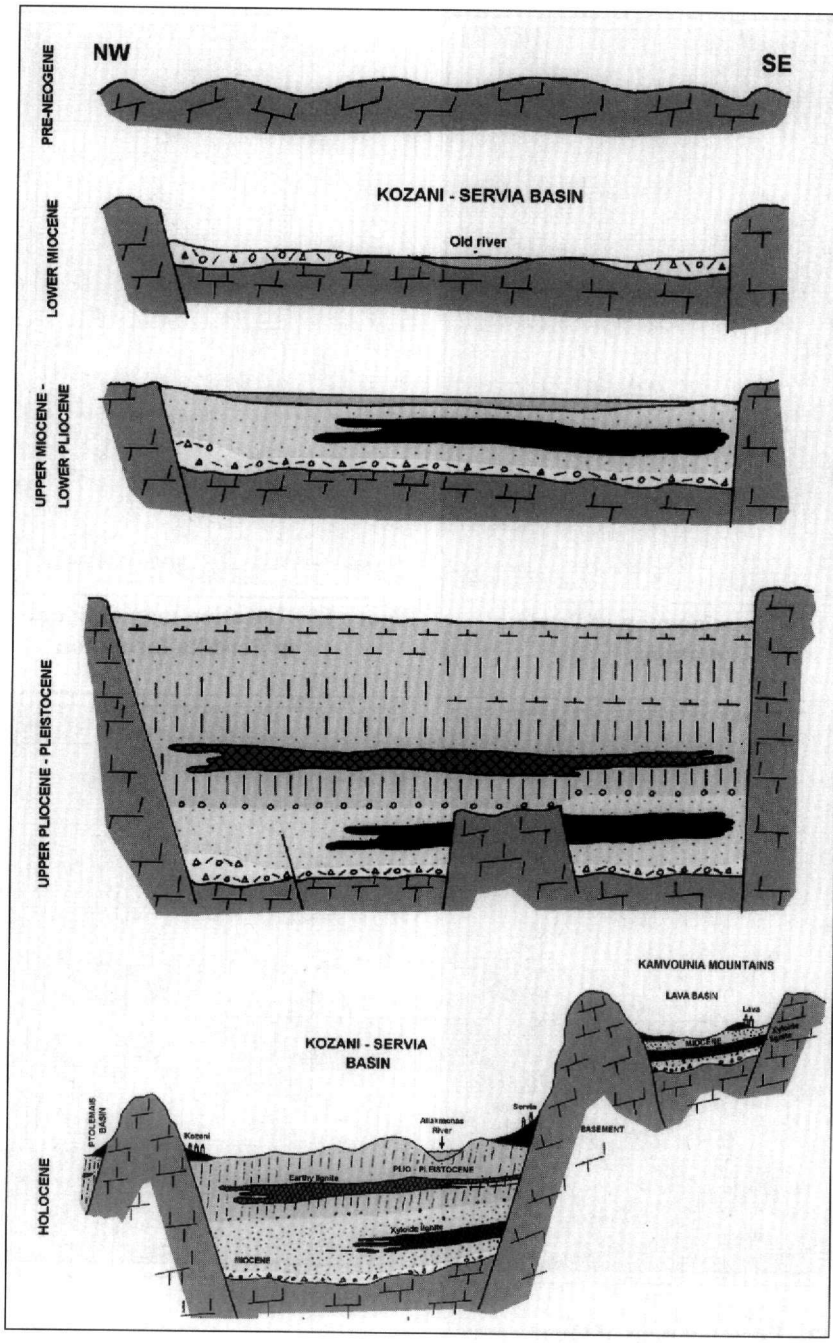

Figure 14 - Evolution of the basin from late Miocene till recently

4. Conclusion

The creation of the graben of Florina, Ptolemaida-Amynteo, Kozani-Serbia, as well as that of Sarandaporo basin, began after the Alpine cycle ended and continues still.

The most important lignite deposits of Greece have been deposited in this graben, developed inside marshy, lacustrine and fluvial-lacustrine depositions whose age is mainly Early Pliocene, Late

Miocene (;).

In the graben and mainly in the Ptolemaida – Amynteo basin, four (4) phases of lignitogenesis have been specified:

- Late Miocene – Early Pliocene (lignite "Xylitic type")
- Early – Late Pliocene (lignite "Geode type")
- Pleistocene (lignite – peat lignite)
- Holocene (peat)

5. Acknowledgments

We would like to thank all our colleague scientists, technologists and technicians who have worked in the area and participated through the results of their research in the synthesis of this paper, and dedicate it to the memory of those who have passed away. Due to limited space we report the Geologists J. Papastamatiou, J. Anastopoulos, K. Koukouzas, Th. Agiotis, D. Dimitriou, the foremen G. Georgopoulos, G. Mitrokostas, Chr. Koutsonas, the technicians J. Anyfantis, K. Christodoulou, Ch. Peglidis.

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