AGE DETERMINATION AND PALEOGEOGRAPHIC RECONSTRUCTION OF PINDOS FORELAND BASIN BASED ON CALCAREOUS NANNOFOSSILS

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ABSTRACT

The study area is part of the Pindos foreland (Underhill, 1985). Pindos foreland is a tertiary turbiditic foreland basin fill trending parallel to the external Hellenides and occupies Gavrovo and Ionian isopic zones (Aubouin, 1959).

The age of Pindos foreland sediments is still a matter of discussion. B.P. (1971) proposed an early Miocene to middle Miocene age, explaining the presence of Oligocene fauna as a product of large scale erosion and reworking of older sediments during Miocene. IGSR&IFP (1966) suggested a late Eocene to early Miocene age for the basin fill while Fleury (1980), Leigh (1991), Wilpshaar (1995), Bellas (1997) assigned an Oligocene age. Avramidis et al. (1999) propose a middle Eocene to early Miocene age assessment, using nannofossil zones from three studied cross sections in the Klematia-Paramythia basin (middle Ionian zone).

The determination of the sediment ages was based on the study of calcareous nannofossils, which came from almost 120 samples covering 11 geological cross sections. The nannofossil marker species that were found in the samples were classified using the biozones proposed by Martini in 1971.

According to the age assessments arose from the studied samples, clastic sedimentation in the study area began in the Middle Eocene, with small differences among the basin. The end of clastic sedimentation seems to be at different times in different parts of the basin.

1 GEOLOGICAL SETTING

The study area is part of the Pindos foreland (Underhill, 1985) and comprises the Epirus, Akarnania and NW Peloponnesus regions. Pindos foreland is a Tertiary turbiditic foreland basin fill trending parallel to the external Hellenides and occupies the Gavrovo and Ionian isopic zones (Aubouin, 1959). The basin is bounded to the east by the Pindos thrust and to the west by the Ionian thrust. The Gavrovo thrust separates the Gavrovo and Internal Ionian zones. In addition to these major thrusts, two minor thrusts divide the Ionian zone into the internal, middle and external Ionian zone (from east to the west) (IGSR&IFP, 1966).

The accumulation of the turbiditic deposits resulted from the deformation of the external Hellenides which migrated in a westward direction. During this migration, the Gavrovo and Ionian zones acted as a foreland basin (Underhill 1985; 1989, Clews 1989, Alexander et al. 1990, Avramidis 1999). Therefore the turbiditic deposits of Gavrovo and Internal Ionian zones are considered as a uniform genetic system (Alexander et al. 1990). The age of Pindos foreland sediments is still a matter of discussion. B.P. (1971) proposed an early Miocene to middle Miocene age, explaining the presence of Oligocene fauna as a product of large scale erosion and reworking of older sediments during the Miocene. IGSR&IFP (1966) suggested a late Eocene to early Miocene age for the basin fill while Fleury (1980), Leigh (1991), Wilpshaar (1995), and Bellas (1997) assigned an Oligocene age. Avramidis et al. (2000) proposed a middle Eocene to early
Miocene age, using nannofossil zones from three studied cross sections in the Klematia-Paramythia basin (middle Ionian zone).

Figure 1: Geological map of the study area. The studied sections are shown by white line, while the dark grey color represents the submarine fan deposits.

2 METHODOLOGY

The determination of the sediment ages was based on the study of calcareous nannofossils, originating from 116 samples, distributed in 11 geological cross sections along the Internal Ionian and Gavrovo zones. Samples were from the base and the top of the section. At the base were over limestones and specifically from transitional beds to turbidites in order to have the exact start age of sedimentation. The cross sections have a west – east orientation and cover the Epirus and Akarnania regions, bounded northwards by the Hellenic-Albanian borders and southwards by the
Corinth gulf. The nannofossil marker species that were found in the samples were classified using the biozones proposed by Martini in 1971 and showed in the following two plates (plates 1 and 2).

Plate 1: 1. *Helicosphaera seminulum*. Section Petrovouni PV1, Upper Eocene, NP18-20, 2. *Dictyococcites scrippae*. Section Petrovouni PV20, Upper Eocene-Oligocene, NP20-23, 3. *Cyclicargolithus floridanus*. Section Agnanta AGN3, Upper Eocene-Oligocene, NP20-23, 4. *Sphenolithus predistentus*. Section Agnanta AGN1, Upper Eocene-Lower Oligocene, NP20-21, 5. *Cribrocentrum reticulatum*. Section Agnanta AGN3, Upper Eocene-Oligocene, NP20-23, 6. *Chiasmolithus solitus*. Section Agnanta AGN3, Upper Eocene-Oligocene, NP20-23, 7. *Helicosphaera recta*. Section Metsovo MB16, Upper Oligocene, NP24-25, 8. *Zygrhablithus bijugatus*. Section Metsovo MB13, Lower Oligocene, NP21-23, 9. *Ericsonia subdisticha*. Section Petrovouni PV1, Upper Eocene, NP18-20, 10. *Nannotetrina fulgens*. Section Palaiopyrgos KB7, Middle Eocene, NP16, 11. *Coccolithus eopelagicus*. Section Agnanta AGN68, Lower Oligocene, NP21-23.

Plate 2: 1. *Helicosphaera recta*. Section Kompoti FLO15, Upper Oligocene NP24-25, 2. *Ericsonia formosa*. Section Amphilochia AMB2, Upper Eocene-Lower Oligocene NP21, 3. *Reticulofenestra oamaruensis*. Section Amphilochia AMB10, Lower Oligocene NP21-22, 4. *Sphenolithus distentus*. Section Kompoti FLO2, Upper Oligocene NP24-25, 5. *Cribrocentrum reticulatum*. Section Pramanta PR35, Upper Eocene NP18, 6. *Coccolithus pelagicus*. Section Elinika AGR9, Upper Eocene NP17-20, 7. *Dictyococcites scrippae*. Section Elinika AGR10, Upper Eocene NP17-20, 8. *Helicosphaera compacta*. Section Elinika AGR9, Upper Eocene NP17-20, 9. *Cyclicargolithus floridanus*. Section Amphilochia AMB2, Upper Eocene-Lower Oligocene NP21, 10. *Dictyococcites bisectus*. Section Amphilochia AMB2, Upper Eocene-Lower Oligocene NP21, 11. *Chiasmolithus expansus*. Section Elinika AGR9, Upper Eocene NP17-20.
3. AGE ASSESSMENTS

3.1. Palaiopyrgos – Kavasila sections

In Kavasila section 6 samples have been studied. The results of the analysis are shown in the following table:

| Sample/strat. level | Age         | Biozone | Nannofossil marker – species in association (in situ)                  | Reworked species                                      |
|---------------------|-------------|---------|-----------------------------------------------------------------------|--------------------------------------------------------|
| KB15/740m           | Late Eocene | NP20-21 | D. bisectus, D. scrippae, C. pelagicus, D. barbadiensis, D. saipanensis, R. umbilica, Cribrocentrum reticulatum, Sphenolithus orphanknolensis, E. formosa |                                                       |
| KB14/610m           | Late Eocene | NP20-21 | Zygryhablithus bijugatus, D. scrippae, Sphenolithus moriformis, C. floridanus, C. pelagicus |                                                       |
| KB18/240m           | Late Eocene | NP20-21 | C. pelagicus, S. moriformis, Cy. floridanus, E. subdisticha, D. saipanensis, R. umbilica, Z. bijugatus |                                                       |
| KB19/170m           | Late Eocene | NP20-21 | Discoaster saipanensis, D. scrippae, C. pelagicus, Cy. floridanus, Z. bijugatus |                                                       |
| KB17/30m            | Late Eocene | NP20-21 | R. umbilica, D. bisectus, Sphenolithus orphanknolensis, E. formosa, Cy. floridanus |                                                       |
| KB16/0m             | Late Eocene | NP20-21 | Cy. floridanus, D. bisectus, Bicolumnus ovatus, S. moriformis, Helicosphaera euphratis, Discoaster tanii, S. moriformis |                                                       |

Table 1: Nannofossil marker species and age determination of the analysed samples in Kavasila section. The stratigraphic level of each sample has been estimated according to Vakalas (2003).

In Palaiopyrgos section 4 samples have been studied. The results are the following:

| Sample/strat level | Age     | Biozone | Nannofossil marker – species in association (in situ)                  | Reworked species                                      |
|--------------------|---------|---------|-----------------------------------------------------------------------|--------------------------------------------------------|
| KB4/               | Late Eocene | NP20    | Ericsonia subdisticha, E. formosa, Dictyococcites bisectus, D. scrippae, Discoaster germanicus, D. tanii, D. septemradiatus, D. binodosus, Reticulofenestra umbilica, Cribrocentrum reticulatum, Coronocycus nitescens, Coccolithus pelagicus, C. miopelagicus, Zygryhablithus bijugatus, Sphenolithus moriformis, S. conspicuus | Strong reworking of Upper Cretaceous, Paleocene, Eocene species. |
| KB5/               | Late Eocene | NP20-21 | Reticulofenestra umbilica, Helicosphaera reticulata, H. euphratis, Cy. floridanus, C. pelagicus, Sphenolithus moriformis, Discoaster deflandrei, D. tanii, D. distinctus, Zygryhablithus bijugatus, Chiasmolithus grandis, E. formosa | Fasciculithus bobii, F. shaubii, Rhomboaster spinus, R. contortus, Towiana eminis, Discoaster lodoensis, D. perpolitus, D. gemmifer |
| KB6/               | -       | -       | Empty sample                                                          |                                                       |
| KB7/               | Middle Eocene | NP16 | Discoaster germanicus, D. barbadiensis, D. saipanensis, D. deflandrei, D. nonaradiatus, D. binodosus, Sphenolithus radians, E. formosa, Reticulofenestra umbilica, R. dyclodia, R. polycomorpha, R. clatara, Micrantolithus vesper, Helicosphaera compacta, C. floridanus, C. pelagicus, C. miopelagicus, D. bisectus, D. scrippae, Zygryhablithus bijugatus | Strong reworking of Paleocene species. |

Table 1: Nannofossil marker species and age determination of the analysed samples in Palaiopyrgos section

3.2. Metsovo section

In Metsovo section two sections have been studied. The first section is located at the road axis that connects Mazia village and Baldouma bridge, while the second ranges from Baldouma bridge to Votonosi village. Although the two sections are continuous, they have been studied separately due to their different tectonic style (Vakalas, 2003).
3.2.1 Metsovo A-A’ section
In Metsovo A-A’ section the following samples have been analyzed (table 2):

### Table 2: Metsovo A-A’ section age determination

| Sample/strat. level | Age            | Biozone | Nannofossil marker – species in association (in situ) | Reworked species |
|---------------------|----------------|---------|------------------------------------------------------|------------------|
| MB10/2200m          | Late Eocene    | NP18-22 | Helicosphaera euphratis, H. compacta, Sphenolithus   |                  |
|                     | Early Oligocene|         | moriformis, Discoaster tani nodifer, D. deflandrei,  |                  |
|                     |                |         | Dictyococcites bisectus                             |                  |
| MB6/1850m           | Middle-Late Eocene | NP17-20 | Reticulofenestra umbilica, R. dictyoda, Braarudosphaera bigelowii, Pontosphaera spp., Ericsonia formosa, Discoaster barbadiensis, Chiasmolithus grandis, Coccolithus miopelagicus |                  |
| MB4/1450m           | Middle-Late Eocene | NP17-20 | Helicosphaera compacta, Dictyococcites bisectus, D. callidus, Discoaster barbadiensis, D. deflandrei, Coccolithus pelagicus, Sphenolithus moriformis |                  |
| MB3/1100m           | Middle Eocene  | NP16    | Reticulofenestra umbilica, R. hillae, Dictyococcites |                  |
|                     |                |         | bisectus, Sphenolithus radians, Coccolithus miopelagicus |                  |
| MB2/400m            | Early-Middle Eocene | NP13-16 | Ericsonia formosa, R. dictyoda, Chiasmolithus consuetus |                  |
| MB1/75m             | Early-Middle Eocene | NP13-16 | Reticulofenestra dicyoda, Discoaster lodoensis, D. barbadiensis, C. pelagicus, C. miopelagicus, Helicosphaera seminulum, Ericsonia formosa, Cruciplacolithus tenuis, Sphenolithus primus |                  |

3.2.2 Metsovo B-B’ section
In Metsovo section 7 samples have been analyzed resulting in the age assessments that are presented in the following table (table 3):

### Table 3: Metsovo B-B’ section age determination

| Sample/strat. Level | Age            | Biozone | Nannofossil marker – species in association (in situ) | Reworked species |
|---------------------|----------------|---------|------------------------------------------------------|------------------|
| MB17/1875m          | Late Oligocene | NP24-25 | Coccolithus pelagicus, C. miopelagicus, D. bisectus, |                  |
|                     |                |         | Cy. Floridanus                                       |                  |
| MB16/1650m          | Late Oligocene | NP24-25 | Sphenolithus ciperoensis (NP24-25), S. moriformis, S. |                  |
|                     |                |         | pseudoradians, Helicosphaera recta (NP24-25), Cy. abisectus, Cy. floridanus, R. umbilica, D. bisectus, Z. bijugatus, Coccolithus pelagicus, Coccolithus miopelagicus |                  |
| MB15/1350m          | -              |         | Coccolithus pelagicus, S. Moriformis                 |                  |
| MB14/1100m          | Early Oligocene | NP22-23 | Reticulofenestra umbilica, Cyclicargolithus floridanus, |                  |
|                     |                |         | Cy. abisectus, Coccolithus pelagicus, Coccolithus miopelagicus, S. moriformis, Dictyococcites bisectus |                  |
| MB13/700m           | Early Oligocene | NP21-23 | Cyclicargolithus floridanus, D. deflandrei, E. formosa, R. umbilica, R. oamaruensis, Z. bijugatus, Helicosphaera euphratis, H. compacta, Sphenolithus predistentus |                  |
| MB12/400m           | Early Oligocene | NP21-22 | Reticulofenestra umbilica, Sphenolithus moriformis, Helicosphaera compacta, Cyclicargolithus floridanus |                  |
| MB11/85m            | Early Oligocene | NP21-22 | Dictyococcites bisectus, Reticulofenestra umbilica, Cy. floridanus, Coccolithus pelagicus, Coccolithus miopelagicus, S. moriformis, D. Deflandrei |                  |

E. Cretaceous and Paleocene species: Quadrum sissinghi, Cr. tenuis, Reworking of Paleocene and Eocene species: Fascicularithus spp., Discoaster wemmelensis, Towieus gammation, Ch. consuetus

Reworked K2 and Paleocene-Eocene species: P. cretacea, Prinias dimorphophus Ch. mutatus, Ch. grandis, Ch. consuetus
3.3 Petrovouni section
In Petrovouni section 10 samples have been analysed (table 4):

| Sample/str. Level | Age      | Biozone         | Nannofossil marker – species in association (in situ)          |
|-------------------|----------|-----------------|---------------------------------------------------------------|
| PV20/1800m        | Late Eocene – Oligocene | NP20-23 | Reticulofenestra oamaruenensis, R. umbilica, Bicolumnus ovatus, Ericsonia formosa, C. pelagicus, Sphenolithus moriformis, Discoaster deflandrei, D. barbadiensis |
| PV19/1750m        | Late Eocene – Oligocene | NP20-23 | R. umbilica, Transversopontis fibula, Ericsonia formosa, C. pelagicus, Sphenolithus conspicius, Discoaster saipanensis, D. barbadiensis |
| PV18/1700m        | Late Eocene – Oligocene | NP20-23 | Sphenolithus moriformis, Helicosphaera intermedia, Ericsonia formosa, C. pelagicus, D. Scrippsae |
| PV17/1650m        | Late Eocene – Oligocene | NP20-23 | Chiasmolithus solitus, D. scrippsae |
| PV13/1100m        | Late Eocene – Oligocene | NP20-22 | C. pelagicus, C. deflandrei, Er. formosa, S. moriformis, H. euphratis, H. compacta |
| PV12/980m         | Late Eocene – Oligocene | NP20-22 | S. montagui, S. moriformis, R. umbilica, Ericsonia formosa |
| PV7/680m          | Late Eocene – Oligocene | NP20-23 | Reticulofenestra umbilica, Discoaster saipanensis, D. barbadiensis, C. miopelagicus, C. pelagicus, Cribrocentrum reticulatum, Cyclicargolithus floridanus, Sphenolithus predistentus |
| PV5/380m          | Late Eocene – Oligocene | NP20-22 | R. umbilica, R. dictyoda, D. deflandrei, Ericsonia formosa, C. pelagicus, Sphenolithus conspicius |
| PV2/30m           | Late Eocene | NP19-20 | C. pelagicus, C. miopelagicus, C. pelagicus, C. deflandrei, Dictyococccites scrippseae, D. scrippsae |
| PV1/0m            | Late Eocene | NP18-20 | Sphenolithus moriformis, Dictyococccites bisectus, Discoaster deflandrei, Helicosphaera intermedia, C. pelagicus |

3.4 Pramanta section
In Pramanta section (southwards of Petrovouni) 13 samples have been analysed (table 5):

| Sample/str. Level | Age      | Biozone         | Nannofossil marker – species in association (in situ)          |
|-------------------|----------|-----------------|---------------------------------------------------------------|
| PR10/3980m        | Late Eocene | NP19-20 | Reticulofenestra oamaruenensis (FO NP20), R. umbilica, Bicolumnus ovatus, Ericsonia formosa, C. pelagicus, Sphenolithus conspicius, Discoaster deflandrei, D. tani nodifer |
| PR12/3290m        | Late Eocene | NP19-20 | C. miopelagicus, Helicosphaera reticulata, Ericsonia formosa, S. moriformis, D. tani nodifer, Reticulofenestra umbilica, Chiasmolithus conspicius |
| PR14/3220m        | Late Eocene | NP19-20 | C. pelagicus, C. miopelagicus, Reticulofenestra umbilica, Chiasmolithus solitus, Chiasmolithus oamaruenensis, Ericsonia formosa, Discoaster tani, D. deflandrei, Dictyococccites bisectus, Ericsonia Formosa |
| PR16/3150m        | Late Eocene | NP19-20 | C. miopelagicus (acme), C. pelagicus, Cribrocentrum reticulatum, Chiasmolithus oamaruenensis, Ericsonia formosa, Discoaster tani, D. deflandrei, Dictyococccites bisectus, Ericsonia Formosa |
| PR43/2570m        | Late Eocene | NP18-20 | Sphenolithus moriformis, Dictyococccites bisectus, Discoaster deflandrei, Helicosphaera euphratis, H. intermedia, C. pelagicus |
| PR39/1900m        | Late Eocene | NP18-20 | Poor sample: Dictyococccites bisectus, Discoaster deflandrei, Ericsonia formosa, Chiasmolithus conspicius, C. pelagicus |
| PR38/1600m        | Late Eocene | NP18-20 | Poor sample: Ericsonia formosa, Reticulofenestra umbilica, Dictyococccites bisectus, Sphenolithus moriformis, S. predistentus |
| PR35/1280m        | Late Eocene | NP18 | Reticulofenestra umbilica, R. dictyoda, Dictyococccites bisectus, D. scrippseae, D. calidius, Ericsonia formosa, E. obruta, Helicosphaera lophota, H. euphratis, C. miopelagicus, C. pelagicus, Sphenolithus moriformis, Cribrocentrum reticulatum |
| PR31/1060m        | Late Eocene | NP18 | Cribrocentrum reticulatum, Discoaster tani, D. barbadiensis, D. saipanensis, D. sublodoensis, Chiasmolithus grandis, C. miopelagicus, C. pelagicus, Helicosphaera compacta, Ericsonia formosa, Reticulofenestra umbilica, Sphenolithus moriformis |
| PR28/930m         | Middle Eocene | NP17 | Reticulofenestra umbilica, Discoaster barbadiensis, D. saipanensis, Ericsonia formosa, C. miopelagicus, Helicosphaera compacta, Ericsonia formosa, Chiasmolithus gigas, Ch. solitus, Discoaster barbadiensis, D. saipanensis, D. tani, C. pelagicus, C. miopelagicus |
| PR23/480m         | Middle Eocene | NP17 | Dictyococccites bisectus (acme), R. umbilica, R. dictyoda, R. umbilica, Chiasmolithus gigas, Ch. solitus, Discoaster barbadiensis, D. saipanensis, D. tani, C. pelagicus, C. miopelagicus |
| PR21/30m          | Middle Eocene | NP17 | Dictyococccites bisectus (acme), R. umbilica, R. dictyoda, R. umbilica, Chiasmolithus gigas, Ch. solitus, Discoaster barbadiensis, D. saipanensis, D. tani, C. pelagicus, C. miopelagicus |
| PR20/0m           | Middle Eocene | NP16 | Reticulofenestra dictyoda, Ericsonia obruta, Dictyococccites bisectus, C. pelagicus, C. miopelagicus |
3.5 Agnanta section

Twenty samples have been analysed in Agnanta section. The results of the analysis are shown in the next table (table 6):

Table 6: Nannofossil marker species and their age assessment in Agnanta section.

| Sample/strat. Level | Age      | Biozone | Nannofossil marker - species in association (in situ)          | Reworked species                  |
|---------------------|----------|---------|----------------------------------------------------------------|-----------------------------------|
| AGN65/3180m         | Oligocene| NP21-23 | Sphenolithus moriformis, Helicosphaera euphratis, H. compacta, Coccolithus pelagicus, Cy. floridanus, D. bisectus, Braarudosphaera bigelowii | -                                  |
| AGN66/3140m         | Oligocene| NP21-23 | Coccolithus miopelagicus, Coccolithus pelagicus, Sphenolithus diastentus, S. moriformis, Cy. floridanus, D. bisectus (abundant), Reticulofenestra clatrata | Reworked Upper Cretaceous and Paleocene, Eocene species. |
| AGN67/3120m         | Oligocene| NP21-23 | Discoaster deflandrei, Reticulofenestra umbilica, R. clatrata, D. bisectus, Coccolithus miopelagicus, S. Moriformis | -                                  |
| AGN68/3070m         | Oligocene| NP21-23 | Poor sample. Coccolithus miopelagicus, Coccolithus pelagicus, Cy. floridanus, E. Formosa | Reworked Upper Cretaceous and Middle and Upper Eocene species |
| AGN62/2700m         | Oligocene| NP21-23 | Reticulofenestra clatrata, R. umbilica, S. moriformis, S. predistentus, Cy. floridanus, Discoaster deflandrei, D. bisectus (abundant), C. miopelagicus, C. pelagicus | Reworked Upper Cretaceous and Middle Eocene species |
| AGN61/2650m         | Oligocene| NP21-23 | C. miopelagicus, C. pelagicus, E. formosa, D. bisectus, Cy. floridanus, Reticulofenestra umbilica | Reworking of Upper Cretaceous species |
| AGN60/2600m         | Oligocene| NP21-22 | D. bisectus, C. miopelagicus, Thoracosphaera spp., Reticulofenestra umbilica, S. Moriformis | -                                  |
| AGN58/2400m         | Oligocene| NP21-23 | Reticulofenestra clatrata, Helicosphaera euphratis, H. intermedia, S. moriformis | -                                  |
| AGN57/2180m         | Oligocene| NP21-23 | C. miopelagicus (abundant), Cy. floridanus, Helicosphaera compacta, Sphenolithus moriformis, D. bisectus, C. Pelagius | -                                  |
| AGN54/1380m         | Oligocene| NP21-23 | Helicosphaera euphratis, Ericsonia formosa, E. obruta, Coccolithus pelagicus, D. bisectus, Cy. floridanus, S. Moriformis | -                                  |
| AGN53/1270m         | Oligocene| NP21-23 | Cy. floridanus - abundant, Sphenolithus predistentus, S. moriformis, C. pelagicus, C. miopelagicus | -                                  |
| AGN48/1060m         | Oligocene| NP21-23 | Cy. floridanus, E. formosa, Thoracosphaera spp., Helicosphaera intermedia | -                                  |
| AGN46/870m          | Oligocene| NP21-23 | Sphenolithus pseudoradians, S. predistentus, C. miopelagicus, C. pelagicus, Dictyococccites bisectus, Cy. Floridanus | -                                  |
| AGN44/810m          | Oligocene| NP21-23 | Sphenolithus moriformis abundant, Transversopontis fibula, Dictyococccites bisectus, Cy. Floridanus | -                                  |
| AGN43/780m          | Oligocene| NP21-23 | Ret. umbilica, R. clatrata, Cy. floridanus, Dictyococccites bisectus, C. pelagicus, C. miopelagicus, Sphenolithus predistentus | -                                  |
| AGN42/700m          | Oligocene| NP21-23 | Cy. floridanus abundant, Helicosphaera willcoxonii, Helicosphaera compacta, S. moriformis, Sphenolithus pseudoradians, C. miopelagicus, Dictyoocccites bisectus | -                                  |
| AGN41/680m          | Oligocene| NP21-23 | Braarudosphaera bigelowii, Helicosphaera compacta, Sphenolithus pseudoradians, Dictyococccites bisectus, D. scrippsae, Sphenolithus moriformis, C. pelagicus, Ericsonia Formosa | -                                  |
| AGN39/630m          | Oligocene| NP21-23 | Poor sample. Small coccoliths | -                                  |
| AGN37/570m          | Oligocene| NP21-22 | Sphenolithus moriformis, Helicosphaera euphratis, H. compacta, Coccolithus pelagicus, Cy. floridanus, S. predistentus, D. Bisectus | -                                  |
| AGN36/500m          | Oligocene| NP21-22 | Ericsonia obruta, E. formosa, C. pelagicus, C. miopelagicus, Cy. Floridanus | -                                  |

3.6 Petas section

Eight samples have been analysed in Petas and showed an Oligocene age.

3.7 Kompoti section

In Kompoti section 9 samples have been analysed (table 7):
Table 7: Korn section age determination.

| Sample/strat Level | Age       | Biozone     | Nannofossil marker – species in association (in situ) | Reworked species          |
|-------------------|-----------|-------------|------------------------------------------------------|---------------------------|
| FLO1/1000m        | Late Oligocene | NP24-25 (NN1?) | D. deflandrei, C. floridanus, Cy. absectus, Coccolithus pelagicus, C. miopelagicus, S. moriformis, D. adamanteus |                          |
| FLO2/900m         | Late Oligocene | NP24-25 (NN1?) | Cy. absectus, C. floridanus, D. deflandrei, Coccolithus pelagicus, Helicosphaera compacta, Dictyococicites bisectus, S. moriformis | Reworked Upper Cretaceous species |
| FLO7/720m         | -         | -           | Coccolithus pelagicus, Cy. absectus και Sph. Moriformis |                          |
| FLO10/680m        | Late Oligocene | NP24-25     | Helicosphaera recta, C. floridanus, Cy. absectus, Coccolithus pelagicus, Sph. moriformis | Reworked Upper Cretaceous and Paleocene species |
| FLO11/420m        | Late Oligocene | NP24-25     | Cy. absectus, Sphenolithus moriformis, Coccolithus pelagicus, C. miopelagicus | Reworked Upper Cretaceous and Paleocene and Eocene species |
| FLO12/400m        | Late Oligocene | NP24-25     | Helicosphaera recta, H. compacta, Coccolithus pelagicus, C. miopelagicus, Cy. absectus, C. floridanus, Sph. Moriformis | Reworked Upper Cretaceous and Eocene species |
| FLO13/380m        | Late Oligocene | NP24-25     | Sphenolithus moriformis, Helicosphaera euphratis, Discoaster calcarulosus, D. deflandrei, Cy. absectus, Coccolithus pelagicus, C. Miopelagicus | Reworked Upper Cretaceous and Eocene species |
| FLO14/150m        | Late Oligocene | NP24-25     | Cyclicargolithus absectus, C. floridanus, Coccolithus pelagicus (acme), Helicosphaera euphratis, H. compacta, H. bramlettei, D. bisectus, D. scruppsae, Sph. Moriformis | Reworked Upper Cretaceous species |
| FLO15/100m        | Late Oligocene | NP24-25     | Cyclicargolithus absectus, C. floridanus, Helicosphaera recta, H. compacta, H. euphratis, D. bisectus (acme), Sph. moriformis, Coccolithus pelagicus, C. Miopelagicus | Reworked Upper Cretaceous species |

3.7 Amphilochia section

Twenty four samples were analyzed in Amphilochia section. The results of the analysed samples are shown in the next table (table 8):

Table 8: Amphilochia section age determination.

| Sample/strat Level | Age             | Biozone     | Nannofossil marker – species in association (in situ) | Reworked species          |
|-------------------|-----------------|-------------|------------------------------------------------------|---------------------------|
| AMB41/3150m       | Oligocene       | NP23-24     | C. pelagicus, Helicosphaera cf. recta, Sphenolithus pseudoradians, S. moriformis, Dictyococicites bisectus, Cy. Abisectus | Late Cretaceous species  |
| AMB40/2600m       | Oligocene       | NP23-24     | Helicosphaera bramlettei, Cy. floridanus, Cy. absectus, Sph. pseudoradians, S. moriformis, C. pelagicus, Pontosphaera multipora | Late Cretaceous species  |
| AMB30/1450m       | -               | -           | Poor sample                                          |                          |
| AMB29/1400m       | Early Oligocene | NP21-23     | Helicosphaera compacta, Coccolithus pelagicus, C. miopelagicus, Cy. Floridanus, D. Bisectus | Early Eocene species     |
| AMB28/1290m       | -               | -           | Poor sample                                          |                          |
| AMB27/1270m       | -               | -           | Poor sample                                          |                          |
| AMB26/1200m       | -               | -           | Poor sample                                          |                          |
| AMB24/1150m       | Early Oligocene | NP21-22     | R. umbilica, D. bisectus, E. formosa, Coccolithus pelagicus, C. miopelagicus, S. Moriformis |                          |
| AMB22/980m        | Early Oligocene | NP21-22     | Sphenolithus moriformis, Coccolithus pelagicus, Cy. floridanus, D. bisectus, Ericsonia formosa |                          |
| AMB21/850m        | Early Oligocene | NP21-22     | Helicosphaera compacta, Cy. floridanus, Sphenolithus moriformis, D. bisectus, R. Umbilica |                          |
| AMB20/800m        | Early Oligocene | NP21        | C. pelagicus, D. bisectus, Cy. floridanus, Ericsonia formosa, Sph. Moriformis |                          |
| AMB19/760m        | Early Oligocene | NP21        | Reticulofenestra oamaruensis, C. pelagicus, D. bisectus, Cy. Floridanus |                          |
| AMB18/730m        | -               | -           | Poor sample                                          |                          |
| AMB14/680m        | Early Oligocene | NP21-22     | Helicosphaera compacta, H. euphratis, Cy. floridanus, C. pelagicus, D. bisectus |                          |
| AMB17/620m        | Early Oligocene | NP21-22     | Coccolithus pelagicus, C. miopelagicus, Reticulofenestra umbilica, Cy. floridanus, Ericsonia Formosa |                          |
| AMB13/550m        | Early Oligocene | NP21-22     | Cy. floridanus, C. pelagicus, D. bisectus, Ericsonia obruta, R. umbilica |                          |
| AMB11/470m        | Early Oligocene | NP21-22     | Dictyococites bisectus, Sphenolithus radians, S. moriformis, S. predistentus, Helicosphaera intermedia | Early Eocene species    |
| Sample/strat. level | Age                  | Biozone | Nanofossil marker – species in association (in situ) | Reworked species |
|---------------------|----------------------|---------|------------------------------------------------------|------------------|
| AMB10/420m          | Early Oligocene      | NP21-22 | Coccolithus pelagicus, C. miopelagicus,              |                  |
|                     |                      |         | Cyclicargolithus floridanus, Sphenolithus predistentus, |                  |
|                     |                      |         | Reticulofenestra umbilica, Helicosphaera compacta, H. |                  |
|                     |                      |         | euphratis, Zygrybalithus bijugatus, E. Formosa       |                  |
| AMB9/410m           | Late Eocene-Early    | NP21    | E. formosa, E. subdisticha, Cyclicargolithus floridanus, | Early Eocene      |
|                     | Oligocene            |         | Sphenolithus predistentus, Dictyococcales bisectus   | species           |
| AMB8/320m           | Late Eocene-Early    | NP21    | Cyclicargolithus floridanus, Sphenolithus predistentus, | Early-Middle      |
|                     | Oligocene            |         | S. moriformis, Dictyococcales bisectus               | Eocene species    |
| AMB7/220m           | -                    | -       | Poor sample                                          |                  |
| AMB5/200m           | Late Eocene-Early    | NP21    | Reticulofenestra umbilica, Dictyococcales bisectus, D.|                  |
|                     | Oligocene            |         | scrippsae, Coccolithus miopelagicus, Cyclicargolithus |                  |
|                     |                      |         | floridanus, Helicosphaera intermedia                 |                  |
| AMB4/170m           | -                    | -       | Poor sample : Dictyococcales scrippae                 |                  |
| AMB2/150m           | Late Eocene-Early    | NP21    | Helicosphaera moorkensis, Sphenolithus moriformis, S. |                  |
|                     | Oligocene            |         | predistentus, Coccolithus miopelagicus, C. pelagicus,|                  |
|                     |                      |         | Dictyococcales bisectus, Cyclicargolithus floridanus,|                  |
|                     |                      |         | Reticulofenestra oamaruensis, R. umbilica, Ericsonia |                  |
|                     |                      |         | formosa                                              |                  |

3.8 Ellinika section

At Ellinika section nine samples were used in order to estimate the period that the clastic sedimentation was active. The results of the analysed samples that were examined are shown at the following table (table 9):

### Table 9: Ellinika section age determination.

| Sample/strat. level | Age                  | Biozone | Nanofossil marker – species in association (in situ) | Reworked species |
|---------------------|----------------------|---------|------------------------------------------------------|------------------|
| AGR2/1800m          | Late Oligocene       | NP24-25 | Sphenolithus distens, C. pelagicus,                  |                  |
|                     |                      |         | Cy. abisectus                                        |                  |
| AGR3/1620m          | Late Oligocene       | NP24-25 | Helicosphaera recta, H. compacta,                    |                  |
|                     |                      |         | Sphenolithus moriformis, S. distensit (NP24-25), C. miopelagicus, C. pelagicus, Dictyococcales bisectus, Cy. abisectus |                  |
| AGR4/1400m          | Oligocene            | NP21-23 | Helicosphaera granulata, Sphenolithus moriformis, Dictyococcales daviesi |                  |
| AGR5/1090m          | Oligocene            | NP21-23 | H. euphratis, Sphenolithus moriformis,               |                  |
|                     |                      |         | Reticulofenestra umbilica, Dictyococcales scrippae, S. predistentus, |                  |
| AGR6/1080m          | Oligocene            | NP21-23 | S. moriformis, S. predistentus, C. floridanus, C. abisectus, C. miopelagicus, C. pelagicus |                  |
| AGR7/690m           | Early Oligocene      | NP21    | Reticulofenestra umbilica, D. deflandrei, S. moriformis, C. pelagicus, Coronocyclus nitescens, Ericsonia formosa, E. Subdisticha |                  |
| AGR8/380m           | -                    | -       | Empty sample                                         |                  |
| AGR9/210m           | L. te Eocene         | NP17-20 | Helicosphaera compacta, Reticulofenestra umbilica, S. moriformis, C. pelagicus, C. miopelagicus, Pontosphaera sp., C. floridanus, Ericsonia formosa, Discoaster barbadiensis |                  |
| AGR10/20m           | Late Eocene          | NP17-20 | C. floridanus, C. pelagicus, C. miopelagicus, Dictyococcales scrippae, D. bisectus, S. moriformis, Reticulofenestra umbilica, R. oamaruensis, Ericsonia formosa, Discoaster barbadiensis | Reworking of Upper Cretaceous, and Paleocene species: M. decussata, A. cymbiformis, Discoaster wemmelensis |

4 CONCLUSIONS

Considering the results of the studied sections the following conclusions can be made:

1. Clastic sedimentation began in the Middle Eocene, with small differences among the basin. Especially in the Metsovo Α-Α' section, a Lower to Middle Eocene age assessment is possible, while in Amphilochia section a delay may have been present, as the lowest stratigraphic sample gave an Upper Eocene-Lower Oligocene age. In the Agnanta, Petas
and Kompoti sections it was not possible to determine the starting point of the clastic sedimentation because the part of these sections which is in contact with the Eocene limestones is covered by recent sediments.

2. The end of clastic sedimentation seems to be at different times in different parts of the basin. In the Krivasila, Palaiopyrgos, Petrovouni and Pramanta sections, which are located at the northern part of the study area, clastic sedimentation stopped at the boundary of Upper Eocene – Lower Oligocene, while in the southern sections including the Metsovo sections the clastic sedimentation stopped in the Upper Oligocene.

3. The end of sedimentation in the Petrovouni and Pramanta sections at the boundary of Upper Eocene – Lower Oligocene is an indicator that Pindos thrust was active at least until this period, as the samples that gave these age assessments are very close stratigraphically to the tectonic contact of the flysch deposits with the Pindos thrust.

4. The fact that in the Metsovo section, which is very close to the Petrovouni and Pramanta sections, the sedimentation lasted for a longer period (Upper Oligocene) is an indicator that the basin was deeper in this area. The presence of the Kastaniotikos line seems to be related with this observation, affecting probably the morphology of the area and eventually the sedimentation.

5. The activation of the Internal Ionian thrust probably took place in the Late Eocene. This is supported mainly from observations in the Metsovo and Pramanta sections where the change from an outer fan to an inner fan environment, which is also pointed out by the modification of the flow regime, took place at this time.

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