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Calcareous nannofossil dating of Ionian and Gavrovo flysch deposits in the External Hellenides Carbonate Platform (Greece): Overview and implications

Maria V. Triantaphyllou *

University of Athens, Faculty of Geology and Geoenvironment, Department of Historical Geology — Palaeontology, Panepistimiopolis 15784, Athens, Greece

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ABSTRACT

The available biostratigraphic data based on calcareous nannofossil analysis determine the mean ages for the onset of flysch sedimentation (base of transitional beds) of the Ionian unit at ~34–35 Ma (external/internal Ionian), and at ~41 Ma (middle Ionian). The top of the Ionian flysch at ~25 Ma constrains the emplacement of Gavrovo nappe, providing an average duration of at least 11–16 Myr for the flysch sedimentation. Gavrovo flysch deposition started at a mean age of ~34 Ma and lasted till ~29 Ma (emplacement of Pindos nappe), suggesting an average duration of approximately 5 Myr. Phenomena of synsedimentary tectonism have been reported at the external Ionian unit, indicating that pre-flysch extension of the basin lasted at least 4 Myr. The ~6–7 Myr difference of the onset of flysch sedimentation between the external/internal and middle parts of Ionian unit implies evidence for an axial symmetry of the basin before the underthrusting of Mani unit under Pindos nappe.

1. Introduction

The Hellenic peninsula is geotectonically divided into the External Hellenides to the west and Internal Hellenides to the east (Brunn, 1956). The Internal Hellenides consist of metamorphic sequences whereas the External Hellenides consist of sedimentary sequences (Aubouin, 1959; Jacobshagen, 1986; Renz, 1955). The External Hellenides Carbonate Platform (Terrane H1) was a continuous shallow water carbonate platform throughout the Upper Triassic–Lias (Papanikolaou, 1997; Papanikolaou et al., 2004; Royden and Papanikolaou, 2011), comprising the well known non metamorphic units of Paxos (Pre-Apulian), Ionian, Gavrovo and Tripolis and their metamorphosed equivalent, Mani unit (Papanikolaou, 1986, 1997, 2009).

The Ionian basin and the shallow-water carbonate platforms to east and west (the Gavrovo and Apulian platforms respectively) were formed during the Early Mesozoic opening of Tethys (Aubouin and Dercourt, 1962). They were originally part of the passive continental margin of the Apulian Plate that was separated from the Pelagonian microplate by an oceanic domain, the Pindos Ocean (Jones et al., 1992; Robertson et al., 1991), during Triassic and Jurassic times. From the Middle Jurassic onward, ophiolite obduction occurred during the closure of this ocean. The External Hellenides Platform is characterised by post-Eocene compressional deformation that still continues in its external parts along the periphery of the active Hellenic Arc. Sedimentary units were overthrusted between late Eocene and early Miocene time, a time interval of 17 Myr (Royden and Papanikolaou, 2011). A model of foreland propagating thrust faults is accepted for the External Hellenides (Brooks et al., 1988; Jacobshagen, 1986; Kamberis et al., 1996; Underhill, 1989), while out-of-sequence thrusting and simultaneous movement of thrusts is supported (Sotiropoulos et al., 2003). The foreland basin was formed as the result of the overthrust loading and the subsequent lithospheric flexure during the migration of the fold-and-thrust belt to the west in the Tertiary period (Clews, 1989; Dercourt and Thiebault, 1979; Fleury, 1980; IGRS–IFP, 1966; Underhill, 1989). Thrusting activity and eustatic sea-level changes control the palaeogeographic evolution of the foreland basin (Avramidis et al., 2002; Kamberis et al., 2005), which is distinguished into the Ionian and Gavrovo basins (Kamberis et al., 2005; Papanikolaou and Lekkas, 2008; Sotiropoulos et al., 2003). Thus, the External Hellenides Carbonate Platform is nowadays part of the active margin of the Eurasian Plate, whose westernmost sector is marked by an impressive, narrow accretionary prism built up by active compressional tectonics (Finetti, 1976; Kokinou et al., 2005; Rabinowitz and Rayan, 1970).

The main difference between the Ionian and the Gavrovo unit is the palaeogeographic change that occurred in the Ionian during Late Lias when the taphrogenetic processes (Karakitsios, 1992, 1995) divided the water platform in two parts. One part (Gavrovo and Tripolis units) remained shallow throughout Late Triassic–Eocene characterised by a thick neritic carbonate succession of about 3000 m, and another part (Ionian unit), formed a deeper basin (Papanikolaou, 1997). The Ionian unit consists of three distinct sequences (Fleury, 1980; Karakitsios, 1992, 1995), a prerift which is represented by shallow water early Liassic lmestones, a synrift that corresponds to the general sinking of the Ionian domain in half-graben geometry, and a postrift sequence

* Tel.: +30 2107274893.
E-mail address: mtriant@geol.uoa.gr.

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with pelagic carbonate sedimentation until the late Eocene. The pre-flysch sediments of the Ionian unit are represented by basinal facies. Great volumes of deep-water sediments, mainly submarine fan deposits (flysch), accumulated in this basin in the syn-orogenic period (B.P. Co. LTD., 1971; Clews, 1989; IGRS–IFP, 1966; Piper et al., 1978). Due to phenomena of syn-sedimentary tectonism, the thickness of transitional beds varies significantly; in several locations transitional beds are missing and flysch rests directly on the limestone (e.g. Kato Retsina; Papanikolaou and Lekkas, 2001, 2008).

Orogenetic processes and flysch sedimentation initiated at early Tertiary (Late Eocene–Oligocene) on both units. The flysch sediments of the Ionian and Gavrovo units were considered in the past as one common succession resting between the Ionian and Gavrovo geotectonic units, the Western Hellenic Flysch (Richter, 1976a) ranging stratigraphically from Late Eocene to Early Miocene (Aubouin, 1959; Dercourt, 1964; Dürr et al., 1978; Fleury, 1980; Godfrieaux, 1968; Katsikatsos, 1969; Papanikolaou, 1986, 1997, 2009; Richter, 1976b; Thiébault, 1982). An internal cordillera (Pindos Cordillera) as a common source terrain is assumed to have supplied the Western Hellenic Flysch through different feeder channels, excluding an intensive reworking of Pindos Flysch sediments (Faupl et al., 1998). Recently Papanikolaou and Lekkas (2008) provided significant lithostratigraphic evidence, implying that the flysch is not continuous and common for both units, and verified the identification of Gavrovo thrust (Sotiropoulos et al., 2008) based on seismic profiles and biostratigraphic analysis. The age of the Ionian flysch deposits at the northern part of the foreland basin at Epirus region, has been determined as Late Eocene–Early Miocene on the basis of planktonic foraminifera (IGRS–IFP, 1966) and calcareous nannofossils (Bellas, 1997). On the contrary the age of the flysch in the Etoloakarnania region has remained a controversial point among researchers for several years. Bizon et al. (1963) when studying planktonic foraminiferal assemblages, have considered the basal flysch deposits that overlie conformably the Ionian and Gavrovo limestones as Oligocene in age, whereas B.P. Co. LTD. (1971) suggested for the same deposits an Early Miocene age, pointing to the existence of an unconformity between flysch and the underlying Eocene limestones. In a recent study, Triantaphyllou in Sotiropoulos et al. (2008) verified the onset of clastic sedimentation in the Gavrovo foreland basin in the Etoloakarnania region, occurring in the Late Eocene/latest Priabonian, confirming previous studies in the area, as also in Epirus region (Bellas, 1997; Bizon et al., 1963; Fleury, 1980; Karakitsios, 1995; Triantaphyllou in Sotiropoulos et al., 2003) and NW Peloponnesus (Kamberis et al., 2005). In SW Peloponnesus, the foreland basin overlies Palaeocene to Eocene Gavrovo neritic carbonates (Fleury, 1980; Thiébault, 1982). According to the above authors, the flysch sedimentation began in the earliest Oligocene, whereas Fytrolakis (1971) considers that it took place in Late Eocene. Earlier, it had already been suggested, on the basis of planktonic foraminiferal assemblages, that the onset of Gavrovo flysch sedimentation took place either in Late Eocene (Priabonian) or Early Oligocene (Bizon et al., 1963).

The present study is an effort to synthesise and critically evaluate all available biostratigraphic data based on calcareous nannofossil analysis, in order to clarify the onset of clastic sedimentation in Ionian and Gavrovo units, refine the stratigraphic age of the Ionian and Gavrovo flysch deposits of the External Hellenides Carbonate Platform and explain the differences in age, duration of flysch sedimentation and thickness of the flysch formations in the two units.

2. Materials and methods

This study is based on a review of published data on the calcareous nannofossil assemblages (Bellas, 1997; Stoykova in Makrodimitras et al., 2010; Triantaphyllou in Pavlopoulos et al., 2010; Triantaphyllou in Sotiropoulos et al., 2008; Stoykova et al., 2003) and compiled with new data produced in this work. The nannofossil data are presented using the standard biozonal scheme (Martini, 1971), as this has been incorporated in the magnetobiochronologic framework (Berggren et al., 1995) and revised concerning the numerical ages (Lourens et al., 2004; Luterbacher et al., 2004). Data have been evaluated and converted, where possible, to more recent calcareous nannofossil schemes available for the considered stratigraphic interval in the Mediterranean area (e.g. Bellas, 1997; Catanzariti et al., 1997; Fornaciari and Rio, 1996).

Concerning the methodology of counting techniques used in the nannofossil studies discussed in this review (see Table 1), mostly semi-quantitative analysis were used, rather than the quantitative studies (e.g. Catanzariti et al., 1997; Fornaciari and Rio, 1996). All involved semi-quantitative analyses results are typically comparable (see Table 1), however the more extensive the analysis is, the more feasible is to face successfully typical difficulties such as scarcity, reworking and preservation state when dating flysch deposits using calcareous nannofossil assemblages. Therefore the analyses listed in column 1 (Table 1), referring to the highest number of fields of view per sample, enabled the finding of the most scarce biostratigraphic indices in the assemblages.

3. Flysch successions and calcareous nannofossil biostratigraphic evidence

3.1. Ionian flysch

Bellas (1997) was the first author to contribute to the biostratigraphic assignment for a number of sections in Epirus/Arta, Prevesa and Parga regions using calcareous nannofossils (Fig. 1; Tables 2 and 3). Elatos section (ref. 1; Tables 1 and 2) in the internal Ionian unit, displaying the transitional beds between carbonate and flysch sedimentation, provided evidence for nannofossil biozone

Table 1
Methodology of counting techniques used in the nannofossil studies discussed in the present study.

1. Triantaphyllou in Sotiropoulos et al. (2008), Pavlopoulos et al. (2010) and present study	2. Stoykova in Stoykova et al. (2003) and Makrodimitras et al. (2010)	3. Bellas (1997)
Extensive semiquantitative analysis in up to 1500 fields of view per slide in longitudinal traverses randomly distributed (15 traverses; 100 fields of view per traverse). The traverses were representing low density material content in order to make accurate nannofossil determinations and trace even the rarest species. Countings of at least 500 specimens have been achieved using a Leica DMLSP optical polarising light microscope at 1250×. Semiquantitative abundances of the taxa encountered were recorded as follows: common: at least 1 specimen/10 fields of view; rare: 1 specimen/10–100 fields of view; present: 1 specimen/> 100 fields of view.	Semi-quantitative evaluation in dense samples under the light microscope with 1250× magnification. The authors have examined their samples extensively; however several important markers were absent or scarce. Then in most cases they used combined range of recorded taxa. The relative abundance was determined as: abundant: more than 10 specimens/field of view, common: 9–2 specimens/field of view, rare: <2 specimens/field of view.	Modified semi-quantitative technique, by selecting an appropriate number and position of traverses at the magnification of ca. 934× (150–170 optical fields of view observed along the long axis of the cover slip and 80–90 fields of view along the short axis). The relative abundance was determined as follows: present: 1–2 specimens after all the traverses were made, rare: 3–5 specimens after all the traverses were made, few: more than 5 specimens and less than optical fields of view/5, common: 1 specimen/3–5 fields of view, abundant: more than 1 specimen every at least 2 fields of view.