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On the origin of terrigenous flysch meta-sediments exposed in the Olympos-Ossa tectonic window (Central Greece): Implications from heavy mineral investigations

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Zur Herkunft schwach metamorpher terrigener Flyschabfolgen im Olympos-Ossa Fenster (Mittelgriechenland): Schlussfolgerungen aus Schwermineraluntersuchungen

Zusammenfassung

Im Olymp- und Ossa-Gebirge Mittelgriechenlands sind schwachmetamorphe Karbonatplattformsedimente in einem tektonischen Fenster, das von Einheiten des Pelagonikums tektonisch überlagert ist, erschlossen. Stratigraphisch reicht die Karbonatabfolge bis ins Eozän, wahrscheinlich bis ins Lutetian. Den Abschluss dieser Entwicklung bilden terrigene Flyschablagerungen. In zahlreichen Darstellungen zum tektonischen Baues der Helleniden wird die Schichtfolge des Fensters paläogeographisch den externen tektonischen Einheiten, im Speziellen der Gavrovo-Zone, zugeordnet. Schwermineraluntersuchungen an den schwachmetamorphen Flyschabfolgen dieser Fenstereinheit erbrachten Apatit- und Zirkon-dominierte Spektren. Diese Schwermineral-Assoziationen unterscheiden sich deutlich von jenen des Westhellenischen Flyschtroges der Ionischen und der Gavrovo-Zone, die durch Granatdominanz und merklichen Chromspinell-Detritus ausgezeichnet sind. Da das Liefergebiet für das terrigene Material des Westhellenischen Flyschtroges nach allgemeiner Auffassung eine interne Position einnahm, sollten diese Granat-dominierten Schwermineralspektren auch in den Flyschablagerungen des Olymp-Ossa-Fensters anzutreffen sein. Die Apatit-Zirkon-Spektren des Olymp-Ossa-Flysches sind gut mit Schwermineralvergesellschaftungen der finalen Flyschablagerungen der Pelagonischen Zone zu vergleichen und unterstützen so die Vorstellung einer internen Herkunft der Olymp-Ossa-Karbonatplattform im unmittelbaren paläogeographischen Nahbereich zum Pelagonikum.

Abstract

In the Olympos and Ossa mountains of central Greece, a low metamorphic grade carbonate platform succession is exposed within tectonic windows through the overlying Pelagonian units. The platform succession, which passes up into the Eocene, and probably into the Lutetian, is terminated by terrigenous flysch sediments. In many models concerning the tectonic structure of the Hellenides, this carbonate platform is palaeogeographically restored to the External Hellenides, especially to the Gavrovo zone. However, the heavy mineral assemblages of the Olympos-Ossa flysch, which are characterized by a dominance of apatite and zircon, differ clearly from those of the Western Hellenic Flysch, deposited in the Ionian and Gavrovo zones, which are rich in garnet and are always accompanied by few percentages of detrital chrome spinel. The source of the terrigenous material of the Western Hellenic Flysch, in the common interpretation, was situated in a palaeogeographically internal position and, therefore, such garnet-dominated heavy mineral assemblages should also be found in the Olympos-Ossa Flysch. However, the apatite-zircon associations found compare very well with those from the terminal flysch sediments of the Pelagonian zone. Thus, they support the idea of palaeogeographically restoring the Olympos-Ossa succession to the neighbourhood of the Pelagonian zone.

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1. Introduction

On the Greek mainland, the northwest-trending Hellenides are divided into an external and internal part (BRUNN, 1956). The External Hellenides comprise, from the west towards the east, the Paxos, Ionian, Gavrovo, Pindos and Parnassos-Ghiona zones, whereas the internal part is built up by the Pelagonian (s. l.), Axios-Vardar, Circum-Rhodope, Serbo-Macedonian and Rhodope zones (for overviews see MOUNTRAKIS et al., 1983; JACOBSHAGEN, 1986). In the Pelagonian zone s. l. an unmetamorphosed western unit, called the Subpelagonian zone, has been separated from an easterly metamorphosed part, known as the Pelagonian zone s. str. The structural evolution of the Hellenides resulted from the collision of the Apulian and Eurasian plates due to closure of the oceanic domains in between. The Axios-Vardar zone represents such a former oceanic realm (BERNOULLI & LAUBSCHER, 1972; JACOBSHAGEN, 1977; GODFRIAUX & RICOU, 1990). Several authors assume a further oceanic domain, the so-called Pindos Ocean (e.g. SMITH & MOORES, 1974; BARTON, 1976; ROBERTSON et al., 1991; JONES et al., 1992), palaeogeographically situated between the Pindos zone and the Pelagonian zone s. l. In this Pindos Ocean model, many but not all of the ophiolites originated in the Pindos Ocean, rather than the Vardar zone. The compressional tectonic events started with obducting ophiolites within the internal parts in the Mid Jurassic. During further orogenesis, subduction shifted westwards into external parts. The last major compressional events associated with nappe stacking in the External Hellenides occurred during the Miocene.

In eastern Thessaly and southern Macedonia, in the Olympos and Ossa region, a low-grade metamorphic succession of recrystallised limestones of Triassic and Early Cretaceous to Eocene age, passing up into terrigenous flysch meta-sediments, crops out in two tectonic windows, the Olympos and Ossa tectonic windows tectonically overlain by the Pelagonian zone s. str. The Ambelakia unit, which contains blueschist rocks, is intercalated between the window successions and the Pelagonian units (KATSIKATSOS et al., 1982). The nature of the Olympos tectonic window was detected by GODFRIAUX (1962), who observed Eocene, probably Lutetian, nummulites in the uppermost parts of the Olympos carbonate succession. In the western part of the Pelagonian zone, in the Kranea area, a tectonic window of less extent exposes similar sequences (SFEIKOS et al., 1991).

The palaeogeographic origin of these window successions is of great importance for the understanding of the tectonic evolution of the Hellenides and strongly influences ideas about the distances of tectonic nappe transport and crustal shortening during Alpine mountain building processes. Recently, two hypothesis about this origin have been discussed.

(1) The carbonate successions represent a platform which originated in the External Hellenides. This hypothesis is supported by the stratigraphic range of the carbonate succession up to the Eocene, probably the Lutetian, and consequently also by the relatively young age of the terrigenous flysch deposits. No bauxite horizons have been detected within the Cretaceous part of the carbonate succession, so that the Parnassos-Ghiona carbonate platform, rich in such bauxite deposits, has to be excluded from these considerations. However, the Triassic-Eocene carbonate platform of the Gavrovo zone, with its terminal flysch sequence commencing in the Late Eocene and palaeogeographically situated between the Ionian and Pindos basins, seems to be a possible source. Such an external origin is, therefore, widely accepted (e.g. FLEURY & GODFRIAUX, 1975; JACOBSHAGEN, 1986; PAPANIKOLAOU, 1989; SCHERMER, 1993).

(2) Another possibility for the origin of the Olympos-Ossa window rocks is that they represent a more internal part of the Hellenides. In the model of ROBERTSON et al. (1991), the carbonate succession originated within the Pindos Ocean, in a more easterly position than the Parnassos platform and separated from the Pelagonian microcontinent by oceanic crust.

In this paper, the authors want to contribute to this discussion by providing new information about the terrigenous material from the flysch sediments in both the Olympos and Ossa windows. If the window successions are of Gavrovo origin, the detrital material should be comparable with the garnet-dominated heavy mineral assemblages, also regularly accompanied by few percentages of detrital chrome spinel, typical of this zone (FAUPL et al., 1994, 1998a). The heavy minerals of the flysch sediments of the Gavrovo, as well as of the Ionian zone, were supplied from an internal source. In this connection, the problem of alteration of detrital heavy minerals during low-grade metamorphism has to be discussed.

2. Geological setting and sample locations

The structural evolution of the Pelagonian zone is summarized by MOUNTRAKIS (1986). The Olympos-Ossa region is composed of several major tectonic units (e.g. SCHERMER, 1993) (Fig. 1). From top to bottom, the Pelagonian zone (s. l.) comprises (1) a dismembered ophiolite unit overlain by Cretaceous limestones; (2) the Infrapierien unit, composed of a metasedimentary succession of Triassic-Jurassic age, underlain by a crystalline rock complex; (3) Palaeozoic granite gneisses of the Pierien unit, also covered by a metasedimentary succession of the Triassic-Jurassic. The Triassic-Jurassic Pelagonian metasedimentary successions are divided into a thin metaclastic and metavolcanic lower sequence followed by neritic carbonates. Pierien and Infrapierien units represent a Hercynian basement with a Permo-Mesozoic cover metamorphosed during Alpine stages. In earlier studies, these Pelagonian units were combined in the Flambouron unit (e.g. PAPANIKOLAOU, 1984). The Pelagonian units are tectonically underlain by the Ambelakia unit (KATSIKATSOS et al., 1982), which contains metavolcanic rocks as well as siliciclastic and carbonate metasedimentary sequences. The metavolcanics are of ocean floor and island arc-type geochemistry (SCHMITT, 1983 cited in ROBERTSON et al., 1991). The deepest tectonic unit forming the core of the windows is composed of the already mentioned Triassic and Cretaceous-Eocene carbonate platform succession, terminated by flysch meta-sediments. This Olympos-Ossa unit crops out in two separate windows. Besides the already mentioned Eocene nummulites from the Olympos unit, further Palaeogene fossils have been found in the flysch around Spilia in the Ossa unit, there, in a marble situated in the upper third of the metaflysch succession of the Ossa unit, nummulites and alveolinas of phantom-like preservation were described by GODFRIAUX & DERYCKE (1978).

The multi-stage metamorphic and structural evolution of this region was described in detail by SCHERMER et al. (1989) and SCHERMER (1990a,b, 1993). In these papers, seven Alpine deformation or metamorphic phases were distinguished from Mid-Cretaceous times on (SCHERMER, 1993, Tab. 1). The Cretaceous D_1 event (~100 Ma) was mainly restricted to the Pelagonian units. In D_2 (53-63 Ma), a blueschist metamor-

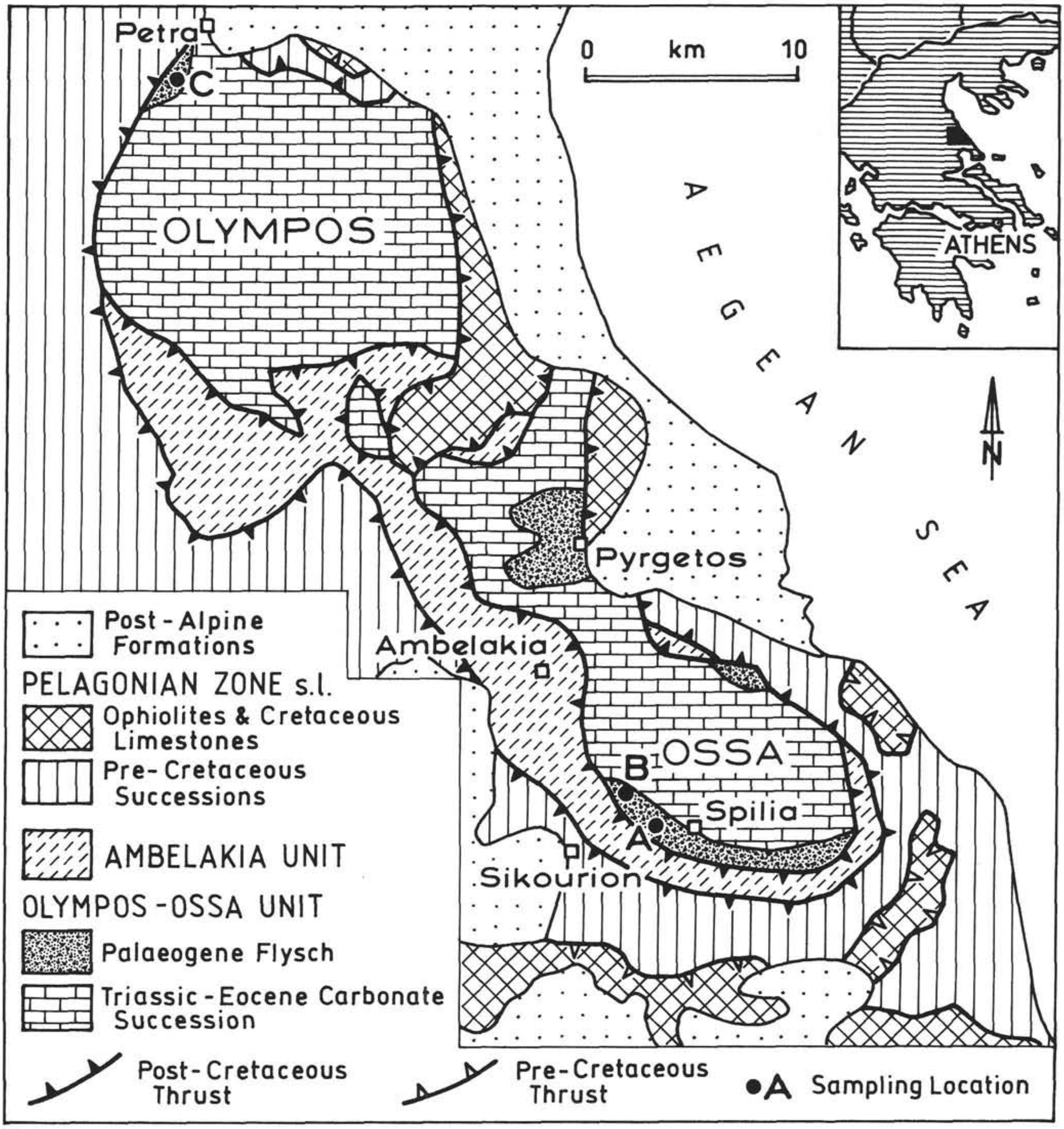


Fig. 1
Geological sketch map of the Olympos-Ossa region, modified from KATSIKATSOS et al. (1982), with the sample locations. A: Pos120-135, Os105-106; B: Os107; C: Oly108-109.

phism was developed in the Pelagonian and Ambelakia unit, while they were thrust towards the southwest. A further pulse of blueschist metamorphism, together with southwest-directed thrusting and folding (D_3, 36-42 Ma), occurred in the Pelagonian and Ambelakia unit, as well as in the Olympos-Ossa units. During this stage, the sedimentary Olympos-Ossa successions were subducted underneath Ambelakia and the Pelagonian nappe pile and suffered an blueschist-pumpellyite metamorphism under P-T conditions between T~200 – 350°C and up to 8 kbar (SCHERMER, 1990a). In the Lower Olympos region, near Kalipefki, the Ossa unit was thrust upon the Olympos unit (KATSIKATSOS et al., 1982). In the early Miocene (16-23 Ma), the exhumation of the deeply buried metamorphic complexes was associated with low-angle extensional faulting (D_5) and was finished by the generation of high-angle normal faults (D_7). Such normal faults border the tectonic windows at their eastern flanks against Neogene and Quaternary deposits.

In the Olympos window, the flysch deposits occur within a NE-SW trending syncline. Samples were taken from two locations, near Petra (Tab. 1). In the Ossa window, sampling followed the outcrops along the Sikourion – Spilia road (Tab. 1). A further sample location is situated on the Spilia – Ambelakia forest road (Tab. 1, Os107). The flysch sediments of the Olympos window appear to be of a somewhat lower metamorphic grade than those in the Ossa window.

Table 1
Coordinates of the sample groups from the Ossa and Olympos flysch successions taken from the topographic map 1:50000 of Greece. For A, B and C see Fig. 1.

Ossa window (Rapsani sheet):		
Sample group A	*Latitude*	*Longitude*
Pos120 to Pos130	39° 47' 17"	22° 38' 04"
Pos131 to Pos135	39 46 07	22 36 28
Os105	39 47 31	22 37 19
Os106	39 47 47	22 38 54
Sample group B	*Latitude*	*Longitude*
Os107	39 48 55	22 35 08
Olympos window (Kondariotissa sheet):		
Sample group C	*Latitude*	*Longitude*
Oly108	40° 07' 38"	22° 17' 04"
Oly109	40 07 36	22 12 12

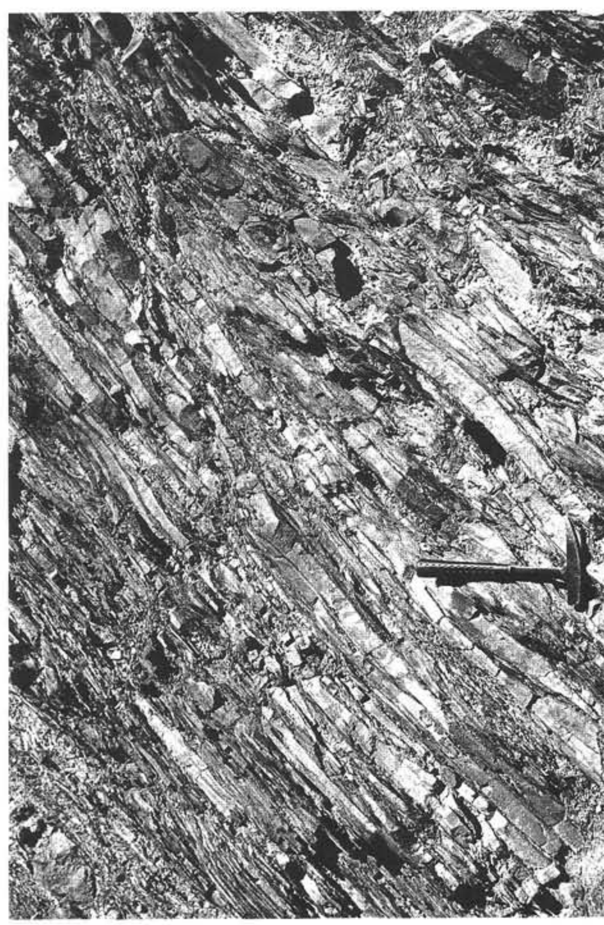
The flysch meta-sediments consist of dark grey metapelitic rocks interlayered by thin-bedded fine-grained metasandstones (Fig. 2a) and a few meta-conglomerates (Fig. 2b). Some of the sandstones are carbonate-cemented. In spite of the metamorphism, the clastic texture of the sandstone is clearly visible in thin-sections (Fig. 3a-d). The detrital grains show the typical "whisker-like" structures within the foliation. The sandstones contain, besides clastic quartz grains of several types, much detrital feldspar, in which plagioclase is clearly dominant.

3. Heavy mineral composition

From the Ossa section, 25 and from the northern Olympos 7 sandstone specimens were prepared for heavy mineral analysis. Heavy mineral separation, using the 0.4 – 0.063 mm sieve fraction, was done as described in detail in FAUPL et al. (1998a). The results of the analysis are shown in Tab. 2.; only 22 representative heavy mineral assemblages could be extracted.

Most of the samples bear high percentages of Ti-minerals (average about 40%), such as sphene or its altered products (leucoxene). The occurrence of sphene was additionally proved by X-ray diffraction. ALDAHAN & MORAD (1986) demon-

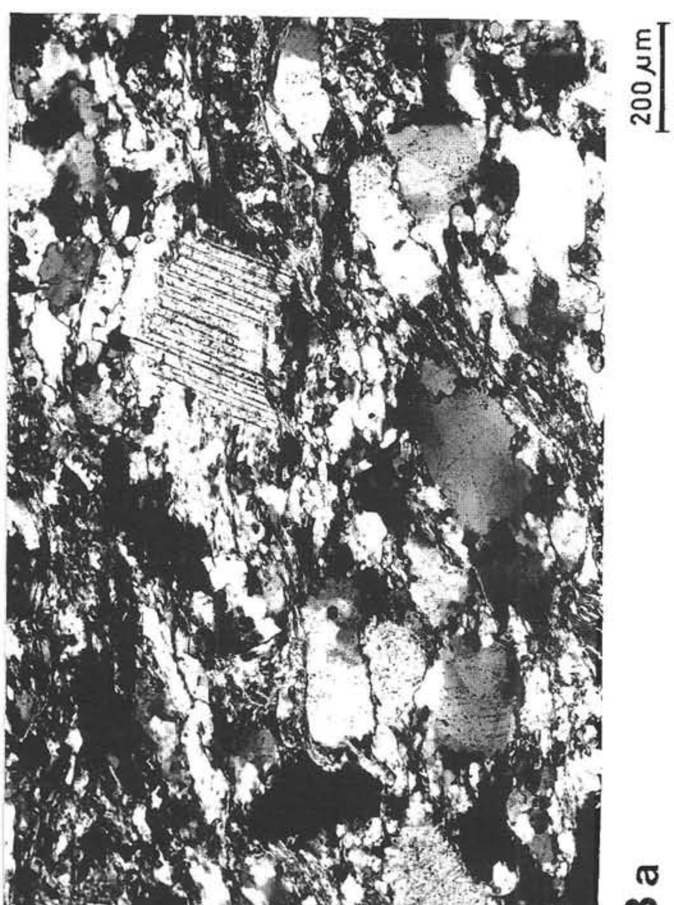
2b



2a

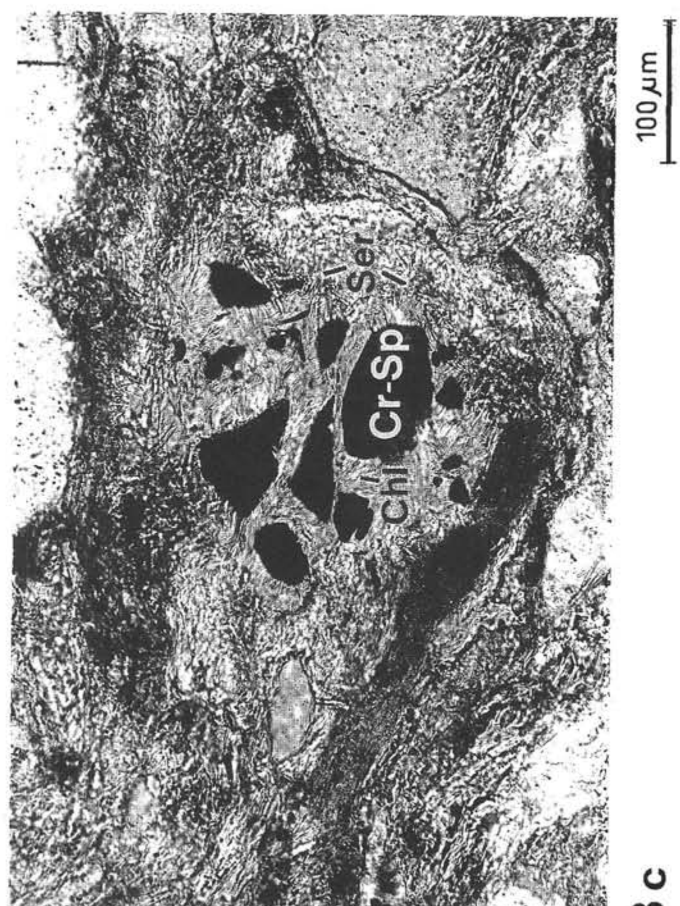
Fig. 2 →
a) Palaeogene flysch formation of the Ossa unit showing the characteristic interbedding of metapelitic rocks with thin meta-sandstone layers. Roadcut Sikourion – Spilia, location Os105. – b) Matrix-supported meta-conglomerate of the Ossa flysch formation demonstrating the foliation and intense folding of the matrix and the deformed pebbles floating in between. Same location as a).

Fig. 3 *siehe nächste Seite*
Micrographs from meta-sandstones of the Palaeogene flysch formation of the Olympos-Ossa unit: a) and b) exhibit characteristic examples of meta-sandstone fabrics demonstrating the preservation of detrital minerals, such as mono- and polycrystalline quartz, and plagioclase. Ossa flysch, Os107/2, crossed nicols. – c) Detrital chrome spinel-bearing chlorite aggregate. The rim is formed by sericitic micas. The faint pink colour of the chlorite in the microscope seems to be indicative for chrome chlorite. Cr-Sp – chrome spinel, Chl – chlorite, Ser – sericitic mica; Olympos flysch, Oly109/1, parallel nicols. – d) Detrital quartz, feldspar, and amphibole within a metamorphic fabric. The amphibole grain (Amph) shows whiskers of fine mica within the foliation. Olympos flysch, Oly109/2, crossed nicols.



3a

3b



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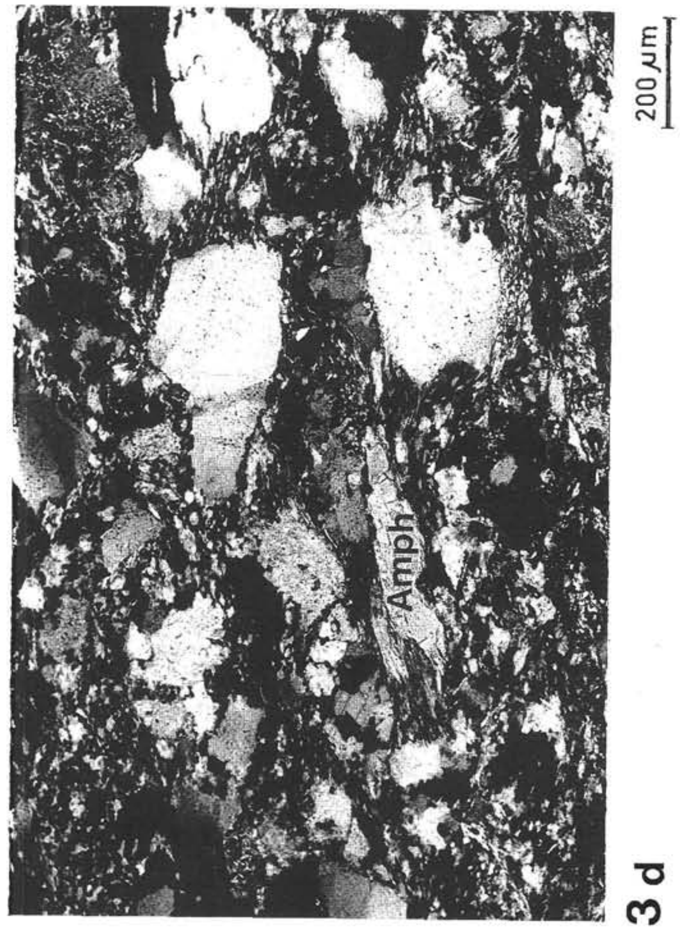

3d

strated that these minerals can form during diagenesis. COOMBS et al. (1976) additionally showed that sphene may grow in pumpellyite-bearing sandstones. For this reason, sphene has not been included into the detrital mineral associations in Tab. 2. Fragments of pumpellyite-aggregates, proved by X-ray diffraction, are also considered to be a metamorphic mineral phase growing during Tertiary metamorphism (SCHERMER et al., 1989). They were particularly abundant in samples from the Mt. Olympos area and are not listed in Tab. 2 because of their non-detrital origin.

All the samples from the Ossa flysch, as well as from location Oly108 of Mt. Olympos, are characterized by stable detrital mineral assemblages composed of apatite (ca. 50%) and zircon (ca. 30%), which are associated with few percentages of tourmaline and rutile. Garnet is a relatively rare component. In the Ossa Flysch, the average content of garnet is <1% (max. 6%). The Olympos samples bear somewhat more garnet (av. of location Oly108 5%) than the Ossa samples. Chrome spinel is, in most cases, totally absent. In sample Os105/4 and Oly109/1, chrome spinel predominantly occurs within chlorite aggregates and is found only very rarely as single detrital grains. In the cases of chlorite-aggregates, chrome spinel is not easily detectable. Such chrome spinel-bearing aggregates were also observed in thin-sections (Fig. 3c), where clear evidence for their clastic nature is available. In sample Oly109/1, the chlorite shows a faint pink colour and a grey colour of birefringence, which appears to be indicative for chrome chlorites (TRÖGER, 1967). Traces of detrital staurolite and epidote-group minerals were also observed. Epidote-minerals reached somewhat higher percentages in samples from the Olympos than from the Ossa flysch.

Table 2
Detrital heavy mineral composition of the Palaeogene flysch successions of the Olympos-Ossa window in grain-%.
Abbreviations: Zir -zircon, Tou – tourmaline, Rut – rutile, Apa – apatite, Gar – garnet, Stau – staurolite, Cr-Sp – chrome spinel, Epi – epidote-group, Amp – greenish amphibole, Oth – Others.[1]) chrome spinel mainly within chlorite-aggregates.

Samples	Zir	Tou	Rut	Apa	Gar	Stau	Cr-Sp	Epi	Amp	Oth
				Ossa window						
os105-1	8.7	6.5	0.0	82.6	1.1	1.1	0.0	0.0	0.0	0.0
os105-2	35.5	4.3	0.0	58.2	0.7	0.0	0.7	0.7	0.0	0.0
os105-3	24.4	4.9	2.4	68.3	0.0	0.0	0.0	0.0	0.0	0.0
os105-4	29.9	6.3	9.4	47.2	0.0	0.0	4.7[1]	1.6	0.0	0.8
os105-5	18.6	1.0	0.0	76.3	1.0	2.1	0.0	1.0	0.0	0.0
os106-1	9.1	9.1	9.1	72.7	0.0	0.0	0.0	0.0	0.0	0.0
os106-2	41.0	7.7	17.9	33.3	0.0	0.0	0.0	0.0	0.0	0.0
os107-1	31.3	1.0	0.0	66.7	1.0	0.0	0.0	0.0	0.0	0.0
os107-2	23.3	1.0	1.9	71.8	0.0	1.9	0.0	0.0	0.0	0.0
pos121	37.4	14.1	9.1	39.4	0.0	0.0	0.0	0.0	0.0	0.0
pos122	25.9	7.0	6.0	60.7	0.5	0.0	0.0	0.0	0.0	0.0
pos123	15.5	5.2	5.2	73.6	0.0	0.0	0.0	0.0	0.0	0.5
pos125	38.2	8.8	2.9	44.1	5.9	0.0	0.0	0.0	0.0	0.0
pos126	29.4	8.8	5.9	55.9	0.0	0.0	0.0	0.0	0.0	0.0
pos128	43.0	11.0	11.0	33.0	2.0	0.0	0.0	0.0	0.0	0.0
pos132	52.6	15.8	0.0	31.6	0.0	0.0	0.0	0.0	0.0	0.0
Mean	*29.0*	*7.0*	*5.1*	*57.2*	*0.8*	*0.3*	*0.3*	*0.2*	*0.0*	*0.1*
				Olympos window						
oly108-1	35.4	2.5	2.5	50.6	5.1	0.0	0.0	1.3	0.0	2.5
oly108-2	31.7	4.9	9.8	31.7	9.8	0.0	0.0	12.2	0.0	0.0
oly108-3	53.8	5.8	3.8	36.5	0.0	0.0	0.0	0.0	0.0	0.0
oly108-4	13.3	3.3	1.7	73.3	6.7	1.7	0.0	0.0	0.0	0.0
Mean	*33.6*	*4.1*	*4.5*	*48.1*	*5.4*	*0.4*	*0.0*	*3.4*	*0.0*	*0.6*
oly109-1	6.4	0.0	0.0	1.3	1.3	0.0	1.3[1]	0.0	88.5	1.3
oly109-2	6.6	0.7	0.7	3.0	0.0	0.0	0.0	7.4	81.7	0.0
Mean	*6.5*	*0.3*	*0.3*	*2.1*	*0.6*	*0.0*	*0.6*	*3.7*	*85.1*	*0.6*

Atypical heavy mineral compositions, in comparison to the other analyses, were found in the two samples from Olympos location Oly109, where nearly monomineralic greenish amphibole assemblages occur, accompanied by a few percent of zircon, epidote and apatite. Tourmaline, rutile, garnet and chrome spinel are detected only in traces. Observations in thin-sections indicate that these amphiboles are definitely detrital grains and not metamorphic products (Fig. 3d).

4. Discussion

For the purpose of comparison with the assemblages obtained from the Olympos-Ossa flysch, the average composition of the detrital heavy minerals of terminal flysch successions from the Gavrovo zone and from selected locations of the eastern Pelagonian zone are shown in Fig. 4.

The heavy mineral assemblages of the terminal flysch successions of the Gavrovo zone, which belongs to the eastern part of the Western Hellenic Flysch Trough, are dominated by a high content of garnet (>60%) and are frequently associated with minor amounts of chrome spinel (av. ca. 8%) (FAUPL et al., 1998a). On the other hand, heavy mineral assemblages from terminal flysch sediments of eastern parts of the Pelagonian zone, such as Skopelos, Evia, Argolis-Adheres and Poros, are characterized by the predominance of stable detrital mineral associations, especially of apatite and zircon. There, chrome spinel as well as garnet, in general, are of subordinate importance or are totally missing (FAUPL et al., 1998b). In contrast to these eastern Pelagonian sample sites, relatively high percentages of garnet and chrome spinel are observed in western Subpelagonian flysch deposits, such as investigated in the western Othrys Mountains or the flysch of Lighourion (Argolis) (FAUPL et al., 1998b).

No similatrity in the composition of the detrital heavy minerals between the flysch sediments of the Gavrovo zone and the Olympos-Ossa windows has been observed, however, such a

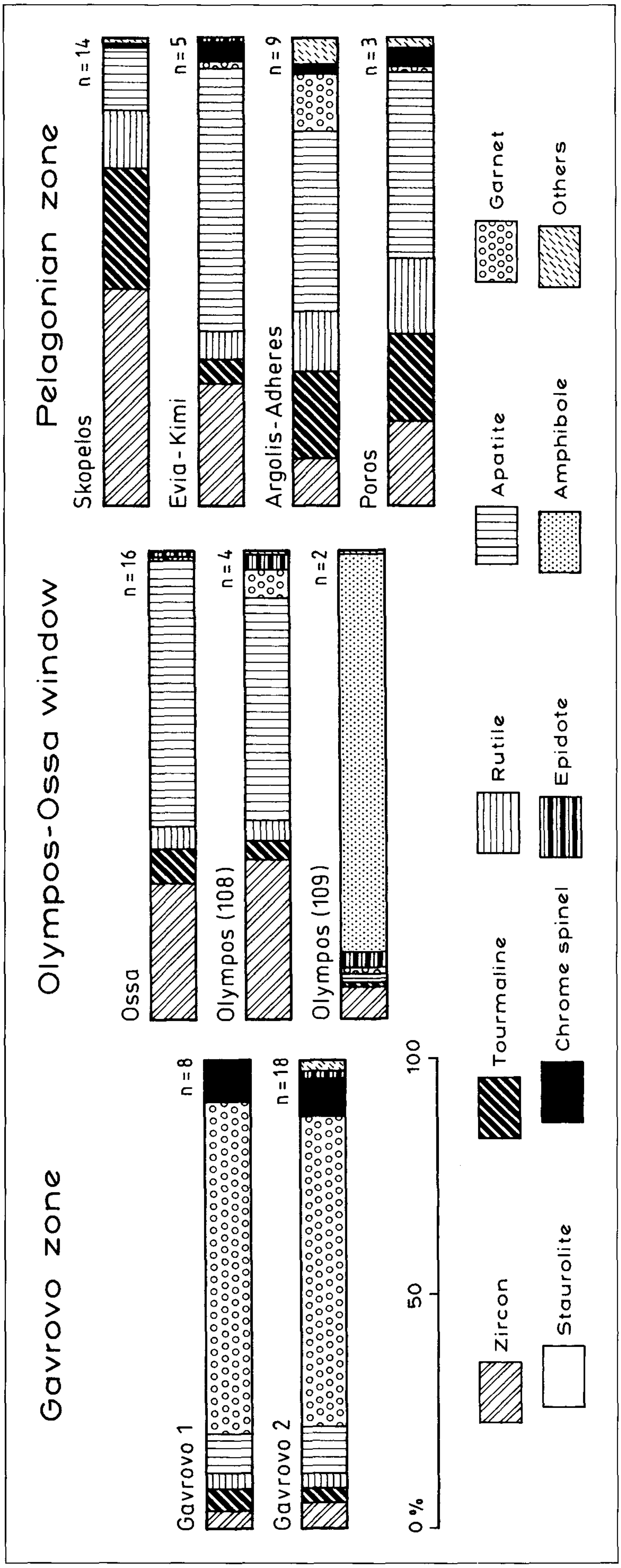

Fig. 4
Average heavy mineral composition of Palaeogene flysch deposits of the Gavrovo zone and the eastern Pelagonian zone in comparison with those of the Olympos and Ossa unit.

correspondence should exist, if the window successions originated within the Gavrovo zone, because a palaeogeographically internal position is assumed for the source areas of the Western Hellenic Flysch Trough (e.g. RICHTER, 1976a, b; PIPER et al., 1978; ALEXANDER et al., 1990; GONZALES-BONORINO, 1996; SCHNEIDER et al., 1998). The same non-correspondence can be seen with the heavy mineral detritus of the Palaeogene flysch of the Pindos and Parnassos-Ghiona zone (FAUPL et al., 1998a).

The predominance of stable heavy mineral associations, such as observed in the Olympos-Ossa flysch, can originate from two different effects. (1) The stable minerals mirror directly a granitoid source area which supplies these minerals abundantly. In the case of the Pelagonian flysch sediments, this explanation is indicated by the sandstone composition rich in feldspar. The sandstones of the Olympos-Ossa flysch also show such a relatively high feldspar content. (2) The stable heavy mineral composition is the product of alterations during metamorphism, in which less stable minerals disappear. The Olympos-Ossa successions suffered such a weak metamorphism, as indicated by the occurrence of metamorphic pumpellyite in the Olympos samples. SCHERMER (1990a) characterized the metamorphic grade in the Olympos-Ossa window by the growth of chlorite, phengite, pumpellyite and to a minor extent by actinolite, prehnite, stilpnomelane, lawsonite and crossite. In the case of such a low-grade metamorphism, if a lot of detrital garnet had initially existed within the sandstones, these garnet grains would show chlorite rims, but would not totally disappear. Also, no evidence could be found that chrome spinel is totally unstable during metamorphism; the chrome spinel-bearing chlorite-aggregates are clearly of detrital origin. Such aggregates were also detected within heavy mineral assemblages of Pelagonian flysch sediments. Examples of the stability of detrital chrome spinel during low-grade metamorphism are well known from the Arosa zone, a Penninic tectonic unit below the Austroalpine nappe pile from the border of Eastern and Central Alps (e.g. LÜDIN, 1987; POBER & FAUPL, 1988). In the Alps, BURKHARD (1993) demonstrated, that the stability of accessory chrome spinel within serpentinites during progressiv metamorphism depends highly on spinel chemistry. Fe-poor Cr-spinels seem to be more restistant than Fe-rich ones. Therefore, the loss of detrital chrome spinel, to a minor extent, has to be expected. The only definite metamorphic alteration within the heavy mineral assemblages of the Olympos-Ossa window is believed to have been observed in the growth of sphene and related minerals. Therefore, the heavy mineral assemblages of the Olympos-Ossa flysch are considered to essentially mirror the primary heavy mineral composition, without originally higher amounts of garnet and chrome spinel. This type of heavy mineral composition is widely distributed in most of the Early Tertiary terrigenous flysch sediments of the Pelagonian zone. The source terrain is dominated by granitoid rock complexes, whereas garnet-bearing rocks and ultramafic ophiolite successions seem to have been only very occasional sources.

The results of these heavy mineral investigations, therefore, support an internal origin of the formations exposed in the tectonic Olympos-Ossa window, palaeogeographically neighbouring the Pelagonian zone, and do not favour an origin in the Gavrovo zone of the External Hellenides. However, it is necessary to mention, that the relatively young stratigraphic age of the Olympos-Ossa flysch, based on fossil findings in the limestones underlying the flysch successions in the Mt. Olympos area, does not fit well with the stratigraphic data of flysch successions of the Internal Hellenides (FLEURY & GODFRIAUX, 1975). As documented by the biostratigraphic survey of RICHTER et al. (1996), the terminal flysch successions of the Pelagonian zone commenced earlier, in the Maastrichtian to Paleocene. These flysch successions young from east towards the west, but for their upper stratigraphic termination within Eocene times only very sparse information is available.

5. Conclusion

The detrital heavy mineral assemblages of the Olympos-Ossa flysch are characterized by the predominance of the stable minerals apatite and zircon. These assemblages are considered to reflect mainly the primary rock composition of the source terrain, which is supported by the immature sandstone petrology, rich in detrital feldspar. Therefore, granitoid rock complexes are believed to have dominated the source area of theses flysch sediments. The occurrence of garnet and chrome spinel in only trace amounts is thought to be indicative of the minor development of garnet-bearing rocks as well as of ultramafic ophiolite complexes in the source area. An intensive alteration of the primary heavy mineral associations during metamorphism is not thought to have taken place.

On the basis of these heavy mineral investigations, the terrigenous material of the Palaeogene flysch sediments of the Olympos-Ossa unit differs considerably from that indicated in the terminal flysch sediments of the Gavrovo zone, as well as of the other isopic zones of the External Hellenides, such as the Pindos and Parnassos-Ghiona zone.

Similar stable heavy mineral assemblages have been reported from the Palaeogene flysch sediments of the Pelagonian zone (FAUPL et al., 1998b). This points to the Olympos-Ossa flysch, having a palaeogeographic position in the neighbourhood of the Pelagonian zone during the Palaeogene. Such a neighbourhood was proposed in the model of ROBERTSON et al. (1991). In the "ROBERTSON-model", the Olympos-Ossa unit lies within the Pindos Ocean, that did not totally close in the Late Jurassic – Early Cretaceous; thus the Olympos-Ossa could have remained undeformed until suturing in the Early Tertiary. However, a better insight in the stratigraphic range of the flysch successions, both of the Olympos-Ossa and the Pelagonian zone, would be necessary to firmly establish this model. In this case, the subduction and nappe stacking processes under low temperature/high pressure conditions during Paleocene and Eocene times were situated at the western margin of the Pelagonian microcontinent, including the oceanic domains of the Pindos ocean, now preserved in the metavolcanics of the Ambelakia unit. The pure A-subduction zone model for the creation of blueschists (SCHERMER, 1990a, 1993) located totally within the External Hellenides is, therefore, not supported by this study.

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