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HEAVY MINERAL STUDIES ON CERTAIN TURBIDITIC SEQUENCES IN THE GREEK MAINLAND: PRELIMINARY RESULTS

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ABSTRACT

In order to characterize the terrigenous material of the flysch deposits of the Ionian, Gavrovo, Pindos, and Parnassos-Ghiona zone, heavy mineral distributions are reported from 10 sections of the Greek mainland. Most of the heavy mineral associations comprise high portions of garnet. Distributions with remarkable amounts of ophiolitic detritus, such as chrome spinel, pyroxene, green amphibole, and epidote, were also observed. Traces of blue alkali amphibole, which were only found in the Ionian and Pindos zone, are important indicators for the existence of high-pressure rocks within the source area. The heavy mineral associations of the so-called „First Flysch" are clearly different from those of the terminal flysch successions.

ΠΕΡΙΛΗΨΗ

Προκειμένου να προσδιορισθεί η προέλευση των κλαστικών υλικών των φλυσχικών σχηματισμών των ζωνών Ιονίου, Γαβρόβου, Πίνδου και Παρνασσού-Γκιώνας, εξετάσθηκε η κατανομή των βαρέων ορυκτών που ανευρέθηκαν σε δείγματα από 10 τομές που πραγματοποίηθηκαν στην ηπειρωτική Ελλάδα. Οι παραγενέσεις των βαρέων ορυκτών διακρίνονται, κυρίως, για την υψηλή περιεκτικότητα σε γρανάτες. Διαπιστώθηκαν, επίσης, παραγενέσεις με αξιοσημείωτη συμμετοχή προϊόντων διάβρωσης οφιολιθικών σχηματισμών, όπως χρωμοσπινέλιος, πυρόξενοι, πράσινοι αμφίβολοι και επίδοτο. Ιχνη κυανών αμφιβόλων, τα οποία εντοπίσθηκαν στις ακολουθίες του φλύσχη των ζωνών Ιονίου και Πίνδου, είναι σημαντικές ενδείξεις για την ύπαρξη, στις περιοχές τροφοδοσίας πετρωμάτων υψηλής πίεσης. Οι συγκεντρώσεις των βαρέων ορυκτών που βρέθηκαν στον αποκαλούμενο „Πρώτο Φλύσχη" της ζώνης της Πίνδου είναι σαφώς διαφορετικές από αυτές του τελικού φλύσχη στην ίδια ζώνη.

1. INTRODUCTION

Turbiditic deep-water sedimentation, commonly referred to as flysch deposits, is a widespread phenomenon in the Cretaceous-Tertiary evolution in both internal and external geotectonic zones of Greece with the exception of the westernmost zone of Paxos. In the Ionian, Gavrovo, Pindos, and Parnassos-Ghiona zone, the flysch deposits are unmetamorphosed or in a stage of anchimetamorpism (FELDHOFF et al., 1993), whereas in the more internal parts of the Hellenides different degrees of metamorphism are observed.

General overviews about the stratigraphy and the geological structures of the flysch belts in the external part of the Hellenides are provided by RENZ

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(1955), BRUNN (1956), AUBOUIN (1957, 1959), IGRS-IFP (1966), BP (1974), DESPRAIRIES (1978), FLEURY (1980), JACOBSHAGEN (1986), among others. Detailed description of the turbiditic facies and related deep-water deposits as well as of palaeogeographic and geodynamic interpretations are given by KOCH & NICOLAUS (1969), RICHTER (1976), PIPER et al. (1978), PIPER & PE-PIPER (1980), PAVLOPOULOS (1981), KATSAVRIAS (1983, 1986), ALEXANDER et al. (1990), LEIGH & HARTLEY (1992), RICHTER & MUELLER (1992, 1993a,b).

Recently, the authors of the present paper started a research program to characterize the clastic material of different flysch successions of the Hellenides on the base of heavy mineral studies. In this paper, only preliminary results from selected sections are presented. The heavy mineral method, as it is applied to flysch deposits of the Hellenides, has already given useful information about palaeogeographic problems and the characterisation of provenance areas in other segments of the Alpine orogenic belt such as in the Eastern and Western Alps (e.g. WOLETZ, 1967; WILDI, 1985; BERNOULLI & WINKLER 1990; FAUPL & WAGREICH, 1992).

2. SAMPLING METHOD AND HEAVY MINERAL PREPARATION

In turbiditic layers, the distribution of heavy mineral grains usually follows the graded bedding. Exceptions are massive and pebbly sandstone beds and several types of mass-flow conglomerates which often show no grading. Therefore, thin turbiditic layers (<10 cm) were sampled as a whole. From thicker layers with significant graded bedding, samples were taken preferably from the lower part of the bed because, in such beds, the amount of heavy grains diminishes rapidly from the base to the top. From most of the samples, thin sections were prepared and, from each, the maximum grain size was measured to control grain size effects on heavy mineral distributions.

For heavy mineral preparation, the sandstone samples were crushed in fragments of few millimeters. The carbonate minerals were dissolved in acidic acid. The dissolution procedure of about 200 g of chrushed material normally lasts up to two weeks. During this time, the acid is frequently renewed. Apatite and other less resistant minerals are not attacked by this acid. For heavy mineral separation, a sieve fraction of 0.4 - 0.063 mm is washed out. The separation is carried out gravitationally using tetrabromoethane (2.96 g/ccm) as heavy liquid. The heavy minerals are mounted in Canada balsam and are examined under the petrographic microscope. In special cases, also X-ray diffractometry is used. More than 200 translucent grains were counted with the ribbon method excluding the minerals biotite, chlorite, glauconite and some undesolved carbonates.

3. GEOLOGICAL SETTINGS OF THE SAMPLING LOCATIONS

In Fig. 1, the locations of sections sampled are indicated within the geotectonic zones of the Hellenides. At present, heavy mineral associations have been studied from the Ionian, Gavrovo, Pindos, and Parnassos zone.

The flysch succession of the *Ionian zone* seems to be connected palaeogeographically with the flysch of Gavrovo zone. The tectonic contact between the flysch of the Ionian zone and the pre-flysch formations of the Gavrovo zone is clearly visible between the Valtos and Makrynoros mountains in central western Greece (PAVLOPOULOS, 1981). The deposition of the flysch of the Ionian zone started during the Upper Eocene and lasted up to the lowermost Miocene (Aquitanian) (e.g. ALEXANDER et al., 1990). The transition from the pelagic limestones of Eocene age into the flysch facies is gradual.

In the present paper, we give information about the heavy mineral distri-

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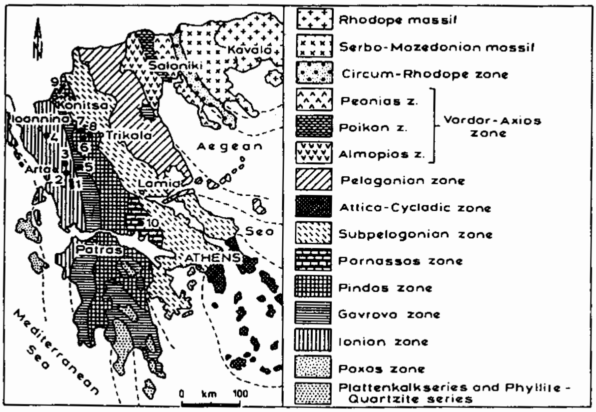

Fig. 1: Map of the geotectonic zones of the Greek mainland (after MOUNTRAKIS et al., 1983) indicating the sampling locations in the flysch units. *Ionian zone*: 1 - southern Makrynoros, 2 - northern Makrynoros and the region of Petas, 3 - southern Athamanika mountains, 4 - Helleniko, SE Ioannina. *Gavrovo zone*: 5 - regions of Astrochori, Elati, and Myrophyllo. *Pindos zone*: 6 - „First Flysch", two sections in the region of Palaeokaria and Stournareika, 7 - „First Flysch" W of Neraidhochori, 8 - Eastern part of the terminal flysch in the Portaikos valley, W of Pyli, 9 - section through the terminal flysch of the northern Pindos. *Parnassos-Ghiona zone*: 10 - section E of Arachova.

Σχ. 1: Χάρτης των γεωτεκτονικών ζωνών της ηπειρωτικής Ελλάδας (κατά MOUNTRAKIS & al. 1983) στον οποίο σημειώνονται οι θέσεις δειγματοληψίας στις διάφορες ενότητες του φλύσχη. *Ιόνιος ζώνη*:1- νότιο Μακρυνόρος, 2- βόρειο Μακρυνόρος και περιοχή Πέτα, 3- νότια Αθαμανικά όρη, 4- Ελληνικό, ΝΑ των Ιωαννίνων. *Ζώνη Γαβρόβου*: 5- περιοχές Αστροχωρίου, Ελάτης, και Μυρόφυλλου. *Ζώνη Πίνδου*:6- „Πρώτος Φλύσχης" της Πίνδου στις περιοχές Παλαιοκαρυάς και Στουρναρέϊκων, 7- „Πρώτος Φλύσχης" δυτικά του Νεραϊδοχωρίου, 8- ανατολικό τμήμα του „Τελικού Φλύσχη" στην κοιλάδα του Πορταϊκού, δυτικά της Πύλης. 9- τομή στον „Τελικό Φλύσχη" της βόρειας Πίνδου. Ζώνη *Παρνασσού-Γκιώνας*: 10- τομή ανατολικά της Αράχωβας.

bution of four sections which are situated in the eastern part of the Ionian zone. The section 1 (Fig. 1) represents the region of southern Makrynoros, the section 2 was sampled in the region of Petas and northern Makrynoros, whereas the location 3 is situated in the southern Athamanika mountains. The transitional zone was investigated near the village Helleniko SE of Ioannina (Fig. 1, sec 4).

The flysch sedimentation in the *Gavrovo zone* started also in the Upper Eocene and lasted up to the end of the Oligocene. At present, we only have informations on heavy minerals from one section (Fig. 1, sec. 5) which is located in the eastern part of the large syncline of Epirus-Akarnania (AUBOUIN & al., 1977; IGRS-IFP, 1966). The flysch successions investigated belong clearly to the Gavrovo zone because of their stratigraphic position above undisputable Gavrovo sediments.In this section, only sandstone turbidites were sampled in contrast to the coarse-grained layers, which can be observed in the regions of Klokova and Varassova mountains, west of Antirrio.

The flysch of the *Pindos zone* extends from the northernmost part of Greece, from the Greek-Albanian border, to the Peloponnesus and from there to the islands of Crete and Rhodos. Within the stratigraphic section of the Pindos zone, thin bedded turbiditic intercalations of Middle Jurassic to early Late Cretaceous age occur. For these turbiditic intercalations, AUBOUIN (1957) used the term „premier flysch du Pinde". At the end of the Cretaceous, the platy limestones of the Pindos zone pass up into a thick turbiditic succession referred to as „second" or „terminal" flysch of the Pindos zone.

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In the northern part of the Pindos mountains, to the north of a transversal axis defined by the rivers Kastaniotikos and Metsovitikos, the entire Pindos zone is confined to tectonic slices of the terminal flysch. In this northern part of the Pindos flysch, ZOUROS & MOUNTRAKIS (1991) reported about tectonic windows of Gavrovo flysch and RICHTER & MUELLER (1992) detected small occurrences of Beotian flysch. KATSAVRIAS (1983, 1986) attributes the entire flysch successions of the northern Pindos to the Gavrovo zone. This opinion, however, is in contradiction with the stratigraphic data provided by RICHTER et al. (1993). On the base of nannofossil investigations, they reported a stratigraphic range of Lower Paleocene up to Upper Oligocene.

To the south of the transversal axis, mentioned above, the flysch occurs in highly compressed synclines, in stratigraphic connection with the pre-flysch formations. The transition between these formations and the flysch successions is formed by up to 100 m thick platy limestones intercalated with turbiditic layers. In this area, the typical flysch deposition started in the uppermost Paleocene (NP9, RICHTER & MUELLER, 1993b) and finished in the uppermost Eocene. In the east Pindos syncline, a maximum thickness of about 4.000 m was assumed for the entire flysch succession by KOCH & NICOLAUS (1969).

Palaeocurrent directions are, in general, directed to the south following the strike of the Pindos zone (RICHTER, 1993).

In the terminal Pindos flysch, two sections were sampled, one in the northern Pindos (Fig. 1, sec. 9) across the road Konitsa-Pentalophos and one in the Portaikos valley, west of Pyli (Fig. 1, sec. 8). The latter one belongs to the East-Pindos syncline.

Thin turbiditic layers of the so-called „First Flysch" of Pindos (Fig. 1 sec. 6 & 7) were sampled in 3 locations. Two of these locations were already described by RICHTER & MUELLER (1993a). They found little affinities to a real flysch facies and, therefore, they proposed the rejection of this term. According to nannofossil investigations by RICHTER & MUELLER (1993) and own observations, the samples collected near Neraidhochori (Fig. 1, sec. 7) and Stournareika (Fig. 1, sec. 6) belong to the Late Turonian-Coniacian (Fig. 1, sec. 7). The third section, in the region of Palaeokaria, is located very near to section 6 (Fig. 1).

In the *Parnassos-Ghiona zone* the transition from shallow-marine rudist-bearing limestones into pelagic limestones occurred during the Maastrichtian. Above these, a sequence of red pelites of Late Paleocene age follows. Between the limestones and the red and grey calcareous shales, a hiatus and a hardground of the Early and Middle Paleocene were observed (SOLAKIUS et al., 1992). The red pelites pass up into the turbiditic succession of the Parnassos flysch, deposited mainly, as in the Pindos zone, during the Eocene (PAPASTAMATIOU, 1960; RICHTER & RISCH, 1981).

Our samples were collected in the road-cuts east of the village Arachova (Fig. 1, sec. 10). The flysch deposits are highly deformed. The lithofacies are sandy-pelitic to sandy, while in some places lense-shaped conglomerates are intercalated. From the turbiditic succession, only south directed paleocurrent indicators were observed (RICHTER & RISCH, 1981).

4. THE HEAVY MINERAL ASSEMBLAGES

Because of the preliminary character of these results, at this state of investigation, we give only typical examples of heavy mineral assemblages in form of diagrams (Fig. 2-6) demonstrating their variability. A detailed analysis and pre-sentation on a much broader sampling base is in preparation.

From the eastern (internal) part of the *Ionian zone* (Fig. 1, section 1-4),

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43 samples were investigated. About 75% of all these samples show a clear predominance of garnet (Fig. 2a). Staurolite and chloritoid occur only in traces. The stable minerals, like zircon, tourmaline and rutile, are represented by a total amount of about 10%, whereas the apatite content lies in 28 samples below 10 % and exceptionally increases up to 20%.

Chrome spinel is a very common constituent in the Ionian flysch. It reaches about 10% in garnet-dominated samples. However, much higher values of up to 50 % are observed in the Dhistraton Fm. and in the Anemorachi Sandstone of section 2 (Fig. 1) as it is demonstrated in Fig. 2b. However, the sandstones of the Dhistraton Fm. and the Potamia Marls sampled in section 3 (Fig. 1), does not contain such high amounts of chrome spinel. The names for these formations were proposed by IGRS-IFP (1966).

The epidote/clinozoisite group is frequently observed with amounts below 5%. Only in a few cases the values increase up to 27% (e.g. Anemorachi Sandstone in section 2). Amphiboles are normally found in traces. Of special interest seems to be traces of blue alkali amphiboles observed in 8 of the 43 samples.

Outstanding heavy mineral associations have been separated from the sandy matrix of a deep-water conglomerate embedded in the Potamia Marls of section 3 (Fig. 1). Besides garnet and chrome spinel, high amounts of amphibole, pyroxene and epidote are typical (Fig 2c), but no blue amphiboles have been found.

Garnet-dominated samples of the transitional beds from the base of the Ionian flysch (Fig. 1, section 4), show conspicuous amounts of pyroxene and epidote, accompanied by traces of blue alkali amphiboles (Fig. 2d).

In the Ionian flysch, statistical analysis reveals no significant correlation between the maximum grain size and the heavy mineral distributions.

The 18 samples of the flysch of the *Gavrovo zone* are characterized, only with a few exceptions, by the predominance of garnet (Fig. 3a). The stable mineral group is only of minor importance (average 11%). In 6 samples, the content of apatite is greater than 10% (Fig. 3b). Together with this elevated apatite content, also higher amounts of sphene are observed. Chrome spinel is always present with a mean value of 8% (max. 14%). Traces of staurolite and chloritoid were only found in 3 samples, but no amphiboles were detected. The sandy matrix of a conglomerate layer shows no differences to the other samples. Fig. 3c exhibits an outstandig association (2 samples) containing a striking amount of epidote and pyroxene.

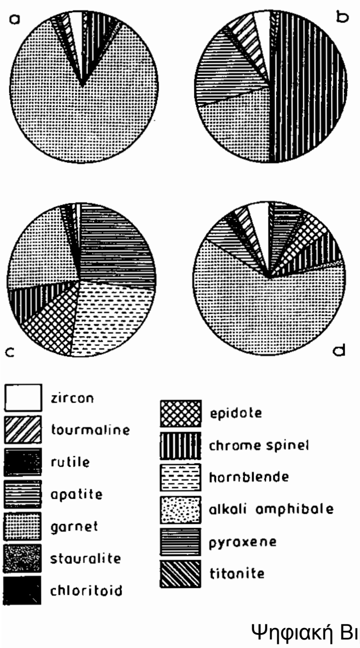

Fig. 2: Typical heavy mineral assemblages from the flysch sequences of the Ionian zone. a) sample 5/1, southern Makrynoros. b) 16/1, Petas region. c) 28/2, southern Athamanika mountains. d) 31/2, transitional beds near Hellenikon.

Σχ. 2: Τυπικές κατανομές βαρέων ορυκτών σε ακολουθίες φλύσχη της Ιονίου ζώνης. a) δείγμα 5/1, νότιο Μακρυνόρος. b) 16//1, περιοχή Πέτα. c) 28/2, νότια Αθαμανικά όρη. d) 31/2, μεταβατικά στρώματα στην περιοχή του Ελληνικού.

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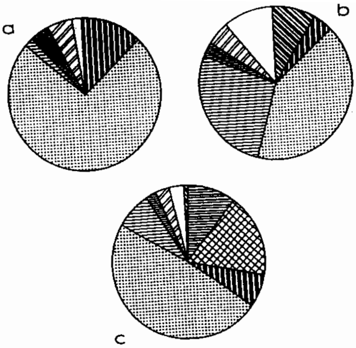

Fig. 3: Typical heavy mineral assemblages from the flysch sequences of the Gavrovo zone, section of Astrochori-Myrophyllon. a)sample 19/1. b) 23/2. c) 20/2. For symbols see Fig. 2.

Σχ. 3: Τυπικές κατανομές βαρέων ορυκτών από ακολουθίες φλύσχη της ζώνης του Γαβρόβου, τομή Αστροχωρίου Μυρόφυλλου. a) δείγμα 19/1. b) 23/2. c) 20/2. Επεξήγηση συμβόλων όπως στο σχ. 2.

The garnet-dominated heavy mineral associations of the Gavrovo flysch are comparable with the garnet-dominated assemblages of the Ionian flysch. However, such high chrome spinel contents, as they are reported from the Ionian flysch (Fig. 2b), have not been observed in the flysch sequences of the Gavrovo zone, until now. In contrast to the Ionian flysch, a relatively clear correlation can be indicated between the maximum grain size of the samples and the content of zircon, apatite, garnet, and, to a less extent, also, of chrome spinel.

The data collected from the so-called „*First Flysch*" of the *Pindos zone* consist of 16 analyses from 3 sections (Fig. 1). RICHTER & MUELLER (1993a) already noted the predominance of zircon, rutile and chrome spinel. Typical heavy mineral associations of the outcrops near Stournareika and W of Neraidhochori are documented in Fig. 4a, b. The associations are characterized by the predominance of the stable mineral group (zircon, tourmaline, rutile; >50%) and the occurrence of high portions of apatite (30%). The content of metamorphic minerals (garnet, staurolite, chloritoid) is relatively small (below 10%). In both sections, chrome spinel is a frequent constituent with values normally below 10%. Only one sample of the Stournareika section contains exceptionally high amounts of chrome spinel (96%). Epidote, amphibole, pyroxene, and sphene appears only in traces. Blue alkali amphiboles have not been observed in either of the three sections.

The heavy mineral associations of the „First Flysch" from the Palaeokaria valley (6 samples) are in striking contrast to the two other sections mentioned above. The samples are characterized by the predominace of chrome spinel and by very small portions of the stable mineral group as well as of garnet and apatite. Fig. 4c and d exhibit two types of these associations. Fig. 4c shows striking amounts of green amphibole and epidote, whereas Fig. 4d represents samples with high contents of green amphibole but without any epidote. One sample from the Palaeokaria valley shows also such very high chrome spinel content, but without any amphibole and epidote.

In the „*Terminal Flysch*" of the *Pindos zone*, two

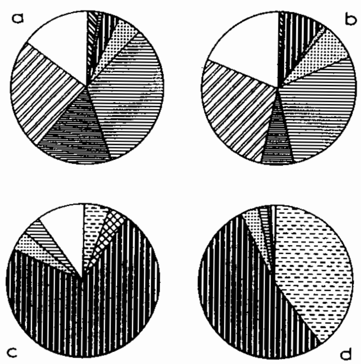

Fig. 4: Typical heavy mineral assemblages from the so-called „First Flysch" of the Pindos zone. a) sample 84/2, Neraidhochori. b) 85/7, Stournareika. c) 51/3, Palaeokaria. d) 51/4, Palaeokaria. For symbols see Fig. 2.

Σχ. 4: Τυπικές κατανομές βαρέων ορυκτών από τον καλούμενο „Πρώτο Φλύσχη" της ζώνης Πίνδου. a) δείγμα 84/2, Νεραϊδοχώρι. b) 85/7, Στουρναρέϊκα. c) 51/3, Παλαιοκαρυά. d) 51/4 Παλαιοκαρυά. Επεξήγηση συμβολισμών όπως στο σχ. 2.

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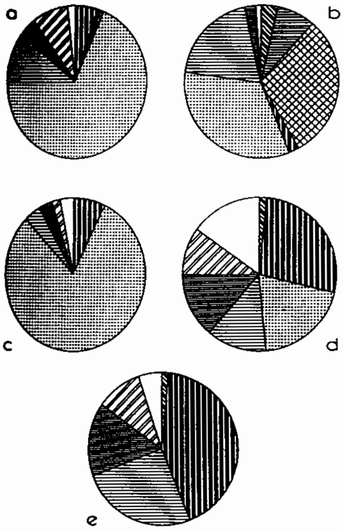

Fig. 5: Typical heavy mineral assemblages from the „Terminal Flysch" of Pindos zone. a) sample 54, Portaikos valley. b) 48, Portaikos valley, c) 35/1, North-Pindos section. d) 33/1, North-Pindos section. e) 36, North-Pindos section. For symbols see Fig. 2.

Σχ. 5: Τυπικές κατανομές βαρέων ορυκτών από τον „Τελικό Φλύσχη" της ζώνης της Πίνδου. a) δείγμα 54, κοιλάδα Πορταϊκού, b) 48, κοιλάδα Πορταϊκού, c) 35/1, τομή βόρειας Πίνδου. d) 33/1 τομή βόρειας Πίνδου.e) 36 Τομή βόρειας Πίνδου. Επεξήγηση συμβολισμών όπως.στο σχ. 2.

sections were sampled (Fig. 1, sec. 8 and 9). Most of the samples bear high amounts of garnet accompanied by relatively small portions of apatite and stable minerals (Fig. 5a, c). In these associations, chrome spinel is quite frequent, but only with low values (about 5%). In two samples of the Portaikos valley (Fig. 1, sec. 8), traces of blue alkali amphiboles were observed. The sample from the transitional beds of the Pindos flysch of the same section belongs also to this garnet-dominated association. In the stratigraphically upper part of the Pindos flysch of section 8, the garnet-dominated sandstones are followed by turbiditic sequences with sandstone beds characterized by high amounts of epidote (ca 30%) and frequent portions of pyroxene accompanying garnet and apatite (Fig 5b). Chrome spinel plays a subordinate role.

In the North-Pindos section (Fig. 1, sec 9), besides the garnet-rich samples, chrome spinel-rich associations can be found which contain striking portions of the stable mineral group (>25%). Fig. 5d indicates such an example with relatively high garnet content, whereas Fig. 5e represents an example without any garnet.

Following the geological sketch map of D. RICHTER et al. (1993, Fig. 2), the heavy mineral associoation indicated in Fig. 5e (rich in chrome spinel and apatite, without garnet) represents a turbidite sequence of Late Eocene to Middle/Late Oligocene age of the western facies of the Pindos flysch. The sandy matrix from the so-called „Juengeres Konglomerat" of the western facies (Middle/Late Oligocene age) contains an outstandig association of very high amounts of pyroxene accompanied by amphibole and chrome spinel. From the middle and eastern facies of this North-Pindos section, at the moment, only few samples are investigated. They all belong to the garnet-dominated associations as indicated in Fig 5a and c. Comparing our results with those published by RICHTER (1993, p. 537), no good correspondence is observed.

In the flysch successions of the *Parnassos-Ghiona zone*, three types of

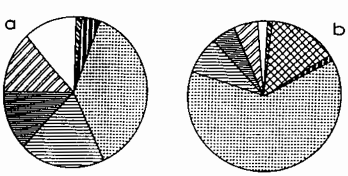

Fig. 6: Typical heavy mineral assemblages from the flysch sequences of the Parnassos-Ghiona zone. a) sample 58/1, E Arachova. b) 60/3, E. Arachova. For symbols see Fig. 2.

Σχ. 6: Τυπικές κατανομές από τις ακολουθίες του φλύσχη της ζώνης του Παρνασσού-Γκιώνας. a) δείγμα 58/1, ανατολικά της Αράχωβας. b) 60/ 3, ανατολικά της Αράχωβας.Επεξήγηση συμβολισμών όπως στο σχ. 2.

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heavy mineral assemblages can be distinguished. In 8 samples, chrome spinel is only of very subordinate significance. Fig. 6a represents an association with high portions of the stable mineral group (45%) and frequent amounts of apatite and garnet. The garnet-rich association (Fig. 6b) is characterized by relatively high amounts of epidote (15%) but only traces of chrome spinel. The heavy minerals extracted from the sandy matrix of a thick conglomerate layer contain a very high chrome spinel content (84%).

5. INTERPRETATION AND DISCUSSION

Important information can be extracted from the heavy mineral associations, mentioned above, about the source area of the non-carbonate extrabasinal clastic material of the different flysch basins of the Hellenides. Also insights can be given in the stage of exhumation of crystalline terrains and ophiolitic bodies. Heavy minerals can also be a helpful tool for distinguishing flysch successions of unknown tectonic position, provided that a well established data set exists. In the Hellenides, in general, the geodynamic evolution of successive flysch basins and data on clast composition point to a predominance of orogen-internal versus external source areas.

The source area of the *Ionian flysch* is characterized by a great extent of mica schist terrains. Low-grade metamorphic series may have played a subordinate role as it is indicated by the occurrence of chloritoid, epidote and chlorite. Areas with gneisses and granitoid rocks, the main sources of zircon, rutile and apatite, were of minor importance. Apart from the broad developed metamorphic terrains, ophiolitic complexes were also commonly exposed in the hinterland of this flysch belt. Especially the content of chrome spinel and pyroxene reflects the abundance of ultrabasic to basic rock types. The heavy mineral association of the sandy matrix of the conglomerates intercalated within the Potamia Marls (Fig. 2c) represents a very local source with high portions of ophiolitic rocks.

The observation that the amount of chrome spinel increases distinctly in the higher stratigraphic levels of the flysch succession of the Petas region is an indication for gradual exhumation of a large ophiolitic terrain. The data available at the moment, are too few to generalize this for the greater part of the Ionian flysch.

The occurrence of blue alkali amphiboles indicates, that also high-pressure terrains were exposed in the hinterland of the Ionian flysch. The circumstance that these blue amphiboles occur only in traces can be explained by the relatively low stability of amphiboles against intrastratal solutions.

In the source area of the *Gavrovo flysch*, such as in the source area of the Ionian flysch, medium-grade metamorphic terrains with huge complexes of mica schists were extensively exposed. Granitoid rocks were also of minor importance. In contrast to the Ionian flysch, ophiolitic rock suites were not so frequent. In the diagram of Fig. 7a the influence of ophiolitic rocks on the heavy mineral associations of the Ionian and Gavrovo flysch is demonstrated. Furthermore, the absence of indications for high-pressure rocks, such as blue alkali amphiboles, seems to be characteristic for the

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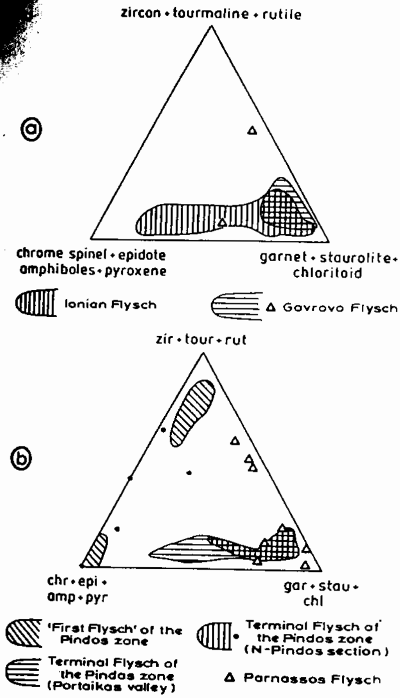

Fig. 7: Comparative triangular diagrams of the heavy mineral distributions. a) Ionian and Gavrovo flysch. b) „First" and „Terminal" flysch of Pindos and Parnassos-Ghiona flysch.

Σχ. 7: Συγκριτικά τριγωνικά διαγράμματα των κατανομών των βαρέων ορυκτών. a) Φλύσχης των ζωνών Ιονίου και Γαβρόβου. b) "Πρώτος" και „Τελικός" φλύσχης της ζώνης της Πίνδου καθώς και φλύσχης της ζώνης Παρνασσού-Γκιώνας.

Gavrovo flysch.

The most outstanding heavy mineral associations have been observed in the so-called „*First Flysch*" (Fig. 7b) of the *Pindos zone*. The turbidites of this Cretaceous successions were fed by two distinct series of source rocks. One consists of extended complexes of granitoid rocks and gneisses, whereas, in the other case, ophiolitic rock suites are common constituents. Mica schist terrains played only a very subordinate role. The ophiolite-dominated turbidites characterize the sampling location in the Palaeokaria valley. There, samples rich in green amphibole and epidote seem to point to extended bodies of altered basic rocks.

Summarising the informations from both sections about the provenance of the *terminal Pindos flysch*, we may say that mica schist terrains were extensively exposed, but also ophiolitic complexes were common. The existence of high-pressure rocks is indicated by minor traces of blue amphibole. Fig. 7b demonstrates that the overall trend in the composition of the hinterland of the Pindos flysch is quite the same as in the Ionian-Gavrovo flysch belt. However, within the realm of the Pindos flysch striking differences were observed. RICHTER (1993) reports about facial changes between the North Pindos and the flysch to the south of the transversal line of Kastaniotikos. In the North Pindos, the heavy minerals of several turbiditic layers indicate that ophiolitic rocks had covered extended regions of the hinterland. In these cases, granitiod rocks and gneisses accompanied these ophiolitic complexes.

In the hinterland of the flysch of the *Parnassos-Ghiona* zone, granitoid rocks and gneisses as well as mica schist terrains played an important role, whereas ophiolitic bodies acted only as a local scource. The palaeogeographic vicinity of the Parnassos-Ghiona zone to the Pindos flysch can not be clearly demonstrated by comparing the heavy mineral associations of these two zones.

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