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GEOTECTONIC POSITION OF THE FLYSCH IN THE EASTERN ALPS, CARPATHIANS, BALKAN AND DINARIDES

(Fig. 1—2)

Abstract: Following manifestations of flysch and its position in the structural plan of tectonic units and its tectonic style in compilation of the Tectonic Map of Carpathian-Balkan countries 1:1 000 000 we have distinguished: 1. Flysch s. s., 2. marlstone flysch or pre-flysch, 3. sandy flysch or coarse flysch, 4. aleuritic flysch, cryptoflysch, 5. heterogeneous flysch, 6. wildflysch, 7. Krasta flysch, 8. Dalmatian type of flysch.

From the standpoint of position of flysch in the history of the orogenic system, ist relation to orogenic processes we distinguish: a) Flysch — predecessor of folding, b) flysch zones from two and more flysch sequences — forerunners and or accompanying several periods of folding, c) flysch zones — particular geosynclines, d) flysch complexes, orifinally troughs, originated with the onset of paroxysms but unaccomplished, representing only an inter-link amidst the upper part of the carbonate formation, e) flysch between two foldings — intraorogenic — filling up negative structures formed by older folding, f) late-tectonic flysch in the hinterland of the flysch geosyncline, g) facies as strange inter-links of limestone formations, characteristic of zones active tectonically.

Arrangement and distribution of individual paleotectonic and geotectonic types of flysch is different in the individual segments of the Alpides; in this regard the article shows the particularities of each segment.

Of importance particular in the Alpide are longer-dated flysch troughs of various type and duration; troughs mostly originated in the Tithonian and Cenomanian. They are founded on deep-seated fault zones; some of them (later) have formed on older troughs.

Relations of the flysch and molasse are various, dependent on the position of the geotectonic zone as well as intensity and type of orogenetic polarity.

Резюме: При исследовании проявлений флиша и его позиции в структурном плане тектонических единиц и его тектонического стиля при составлении тектонических карт Карпато-Балканских стран 1 : 1 000 000 мы различаем: 1. флиш с. с., 2. мергелистый флиш или предфлиш, 3. песчанистый флиш, или грубый флиш, 4. алевритовый флиш, криптофлиш, 5. гетерогенный флиш, 6. «дикий» флиш, 7. Краста флиш, 8. далматический тип флиша.

Исходя из позиции флиша в истории горообразовательной системы его отношение к орогенным процессам: а) флиш — предшественник складкообразования, б) флишевые зоны из двух и больше флишевых слоев — предвещающих или сопровождяющих большее число периодов складкообразования, в) флишевые зоны — отдельные геосинклинали, г) флишевые комплексы, первоначальные троги, которые возникли при наступлении пароксизмов, но незаконченные, представляющие только промежуточное звено в верхней части карбонатной формации, д) флиш между двумя складчатыми процессами — внутриорогенетический — заполняющий отрицательные структуры, возникшие в результате более древнего складкообразования, е) позднетектонический флиш в тылу флишевой геосинклинали, ж) фации как чуждые промежуточные члены известковой формации характерные для тектонически активных зон.

Расчленение и расположение отдельных палеотектонических и геотектонических типов флиша различно в отдельных сегментах альпид; в этом отношении данная статья указывает на особенности каждого сегмента.

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Особенное значение имеют в альпидах более длительно продолжающиеся флишевые троги разного типа и продолжательности; троги которые в особности возникли в титоне или в бериасе. Они расположены на глубоких зонах разломов; некоторые более молодые возникли на более древних трогах.

Взаимосвязь флиша и молассы различна, в зависимости от позиции геотектонической зоны и также интенсивности и типа орогенетической полярности.

In spite of known relations of the flysch to tectonics a whole series of questions about its genesis remains unclear. Compiling the tectonic map 1 : 1 000 000 of a region relatively heterogeneous tectonically including the Eastern Alps, Carpathians, Balkan, Dinarides and Hungarian Median Mass we were paying particular attention to the flysch complexes in two regards: a) to manifestations of the flysch in the structural plan of the individual units; b) to relations of thicker flysch strata to processes of folding in time and space.

Manifestation of Flysch in Structural Plan

In the tectonic map of the Eastern Alps-Carpathians-Balkan and Dinarides we distinguished 8 types of flysch also from the standpoint of tectonics. The division followed structural objectives; the distinguished types are paleotectonic categories with variaous liability to folding. Each of the mentioned types is characteristic of certain tectonic unit or its considerable part. It provides the material base for formation of its tectonic style.

In considerable part of the flysch from the point of view of structure its thickest complexes are to be taken into account in the first place similarly as in the majority of other formations. They form the bearing construction of tectonic units or of parts of them. A factor important is the degree of their liability to folding and the ratio of competent strata to accompanying thicker non-flysch rocks inside them.

We define the eight types of flysch distinguished from the standpoint of tectonics as follows (fig. 1):

1. Flysch s. s. is much liable to folding with folds of smaller dimensions, it increases variety of the structure of nappes in the West Carpathians, most abundant in the nappes of the Eastern Alps. From lithological point of view it is a fine rhytmical flysch.

2. Pre-flysch (marlstone flysch). Shows the style of folds, usually upright but also interrupted by reverse faults; frequently finely refolded (Tešín nappe of the West Carpathians, essential part of the nappes of Ceahlau, Severin in the East Carpathians). Its most typical representative are the Sinaia Beds (marlstone-claystone complex with intercalations of sandstone, marly limestones).

3. Sandy flysch — coarse flysch with banks to masses of sandstones, forming the substratum for folds with a long radius of curvature. It forms the core part of nappes. In the lower part of the front of nappes lenticular and imbricate styles are found, originated by piling up of more plastic members and their tectonic reduction. An example is the Godula nappe in the West Carpathians (Zd. Roth 1972).

4. Aleuritic flysch (cryptoflysch) with predominating claystones with intercalations of sandy limestones, limestones, silts and sandstones and with layers of marls, showing the style of small slices. More compact layers of limestones or sandstones form upright klippes. A typical representative is the Subsilesian nappe of the West Carpathians, also the Audia nappe in the East Carpathians.

5. H e t e r o g e n e o u s f l y s c h characterized by variability in the type of flysch, not only in vertical but also in lateral direction. A typical example is the Mureš unit in the East Carpathians. In its western partial unit the sequence of members is as follows: aptychus beds with ophiolites and jaspers — Tithonian; marlstone flysch — Neocomian; sandy flysch — Barremian to Lower Albian; flysch with volcanics — Senonian. However, more eastwards the sequence is: sandy flysch — Barremian; marlstone flysch with agglomerates — Aptian; aleuritic flysch lying discordantly — Upper Albian; wildflysch — Cenomanian; flysch s. s. — Senonian. Beside the changes of flysch types a considerable amount of wildflysch and volcanic rocks belongs to the particularities. The heterogeneity in the content is manifested in the tectonic articulation into a series of slices, each with a different type of flysch, separated from one another by reverse faults following the planes of material discontinuity.

6. W i l d f l y s c h with thick conglomerates is often a facies accompanying the sandy flysch and heterogeneous flysch only. Independently as a structure it is shown as the mass of the Bucegi Conglomerates in the East Carpathians, not much liable to folding.

7. A heterogeneous type of flysch is the K r a s t a f l y s c h occurring in the Zukali unit in the Albanides. A considerable variability of facies is also typical of it. In the lower part (Maastrichtian-Danian) it is predominantly of carbonate character, where marlstones, partly variegated, alternate with limestones. Higher up, amidst sandstones of an argillite flysch organodetrital and nummulite limestones, conglomerate and limestone olistholites are abundant; wildflysch facies are frequent. The uppermost parts (Priabonian) are represented by a predominantly sandy flysch only with thinner argillite layers. The heterogenity of material is also shown in the complicate imbricate structure giving rise to tectonic complicatedness of the Zukali-Krasta unit (T. B i c o k u, A. P a p a et al 1970).

8. In the most Dinaride units, mainly in the zone of the Dalmatian folds and the Velki Krš unit, the flysch is characterized by thick layers of organogenic limestones forming its more competent fringe. They condition not only its genetic but also structural linking with the underlying limestone complexes (B. S i k o š e k, W. M e d w e n i t s c h 1968). We distinguished it as a particular type and called the D a l m a t i a n t y p e. In the East Carpathians a similar type is found in the outermost unit — Unite marginale (J. D u m i t r e s c u et al 1963).

Relation of Flysch to Processes of Folding-Geotectonic Types of Flysch

However, the structural share of rock complexes in formation of tectonic styles is dependent on their geotectonic and spatial position in the first place. As style-forming elements the individual flysch complexes are manifested mainly where they are folded ouf from particular flysch troughs and / or partial geosynclinal structural-facies zones. However, the flysch occurs more often only as the upper part of limestone and / or limestone-marlstone sequences, linked with the substratum structurally. In such cases it makes the structure of these units only more variegated proportionally to the degree of liability to folding, e. g. in the Krížna nappe of the West Carpathians. In the case of more complicated refolding, mainly in nappe units, the flysch complexes form the filling of slices and digitations in the fronts of nappes, e. g. in the High Tatra unit of the West Carpathians (M. M a h e ľ 1967).

A feature characteristic of the flysch is beside its sedimentological properties also its particular position in the history of the folded system, its relation to processes of folding; therefore it is quite generally considered as orogenic formation. The opinion of the flysch as predecessor of folding in time and space respectively as formation connected with orogenesis of the inner zones (J. A u b o i n 1967), however, requires completion. In the extension of the Carpathians, Balkan and Dinarides several types of flysch are to distinguish according to relation to folding (M. M a h e ľ 1972).

a) F l y s c h - p r e d e c e s s o r o f f o l d i n g: represents the uppermost member of the sequence of sediments. It usually rests without interruption on sediments of the pre-flysch stage. Alone it is immediately pre-tectonic. This type is wide-spread in the Dinarides and Albanohelenides, where practically each tectonic unit terminates with flysch prior to its folding. With polarity of folding a flysch becoming always younger may be followed here from the more inner towards the more outer units: in the Inner Dinarides the flysch is Maastrichtian—Danian, in the Visoki Krš, Budva-Zukali-Krasta zone Maastrichtian—Eocene, in the Dalmatian zone (nappe of Učka) and Kruja-Gavrovo Priabonian—Oligocene, in the Ionian zone Upper Eocene to Lower Miocene (B. S i k o- š e k, W. M e d w e n i t s c h 1965, T. B i c o k u, A. P a p a 1970, J. A u b o i n, J. N d o j a j 1964).

In the South Carpathians the flysch is Upper Cretaceous (prior to the Early Paleogene period); in the Balkan (central and eastern block) Tithonian—Lower Cretaceous and Lower—Middle Eocene, preceding Middle Cretaceous and Pyreneic folding; the inner units of the West Carpathians (Krížna-Tatride) have Middle Cretaceous (Albian—Cenomanian) flysch immediately preceding Cretaceous folding, similarly in the釋 internide units of the East Carpathians (Transylvanian and Bukovinian nappes), in the Apusins (Codru-Moma and Bihor) and Eastern Alps (Frankenfels nappe). There is often marlstone flysch and flysch s. s. accomplishing the carbonate stage.

The flysch, predecessor of folding, is manifested structurally as a section, the upper part of tectonic units. Owing to predominantly good liability to folding it brings about tectonic variety. In nappe units it is piled up, refolded and digitated in the frontal part of the nappe. In accompaniment of underlying limestone complexes of cordillera type with a tendency to the style of upright slices and klippes it forms the filling of these more competent bodies, their tectonic cement. In the most Dinaride units the flysch is usually manifested autonomically owing to considerable thicknesses and the presence of thicker layers of limestones, which are able to form the cores of folded structures

b) More complicated is the f l y s c h z o n e c o n s i s t i n g o f t w o a n d m o r e f l y s c h s e q u e n c e s — forerunners accompanying and preceding several paroxysms of folding. The individual flysches are separated from one another by discordances or non-flysch complex of small thickness. As mainly zones of high tectonic activity are concerned, it is also reflected in the variety of flysch types. In the Mureš and Vardar zones the flysch is Lower Cretaceous, also partly Tithonian and Upper Cretaceous (J. D u m i t r e s c u et all 1962); in the Luda Kamchyia zone in the Balkan the flysch is Upper Cretaceous and Early Paleogene (E. B o n č e v 1966). The flysches of the Klippen Belt of the West Carpathians, Middle but also Upper Cretaceous and Paleogene in age, should be included in this type. The variegation of flysch is emphasized by the facies of the Scaglia rossa, couches rouges or Púchov Marls — cryptoflysch in the sense of V a s s o e v i č; in places also the type of heterogeneous and flysch accompanied by volcanics is spread. The variety in material of the flysch complexes is reflected in the variegation of the tectonic style, imbricate, sometimes even klippen-like.

c) T h e F l y s c h z o n e of the Carpathians and Eastern Alps has a particular type of the flysch association formed in a characteristic l o n g - d a t e d g e o s y n c l i n e, founded partly on a platform in the fore-land of the accomplishing inner geosyncline of particular Alpine type with the onset of the first Cretaceous paroxysms; folded out in later Tertiary periods of folding. Distinct of this zone is an intense sedimentation in the time of Cretaceous foldings intensely manifested in its hinterland without marked manifestations of processes of folding in it. A rebound of the paroxysms of folding are mainly the changes of flysch types as a consequence of changes in paleogeography of the area of deposition. In the first stage. Tithonian—Lower Cretaceous, sedimentation is little variegated, mainly of marlstone flysch, later differentiated in facies in vertical as well as horizontal direction, according to the individual zones. Abundant is the fine rhytmical and sandstone flysch, however, in some zones also cryptoflysch facies are present mainly the couches-rouges. In the terminal stage the late flysch is abundant, with transition into flyschoid respectively molassoid with gradual disappearance of flysch marks. It is genetically connected with originating molasse. The extensive flysch geosyncline, dissected paleotectonically, was transformed into a series of tectonic units of nappes of higher and lower order by processes of folding. In formation of tectonic units primary dissection of the area of deposition as well as types of material of flysch were manifested in the first place. The latter ones played an important role in accomplishing of the tectonic style (secondary) in the individual nappe units.

d) Flysches originated with the onset of Cretaceous diastrophism (in the Tithonian) in troughs (Lužnička zone in the South Carpathians, western block of the Fore-Balkan and Balkan) but also (in the Upper Neocomian) still prior to termination of the sequence, replaced by limestone facies. They are an inter-link of the upper part of limestone sequences. Owing to their thickness they appear quite autochthonously in structure. In both cases a flysch refelded in detail is concerned, partly of marlstone character, partly flysch s. s.

e) Flysch formed between two foldings — most frequently as forerunner of folding of a younger period — filling up negative structures created by earlier folding. For instance, the Paleocene flysch in accompaniment of couches rouges in the Northern Calc Alps terminates the set of facies variable in horizontal as well as vertical direction (marls, sandstones, conglomerates, rudist limestones, often facies of molasse type). With later foldings of the Paleogene period this formation was incorporated into Cretaceous units and this way its superimposed character has been concealed. Such types of flysch are particularly abundant in the South Carpathians, where the manifestations of Cretaceous folding were not more intense. In the Danubicum mainly the sandy flysch occupies the essential part of Upper Cretaceous sediments. A more distinct graben-like character, owing to younger longitudinal faults, appears to display the Upper Cretaceous filling with more subordinate representation of flysch in the Timok zone. The flysch is accompanied by facies of cryptoflysch, molasse with coal seams and organogenic limestones, also thick intraorogenic volcanics. An analogous situation is also in the Srednogorje zone of the Balkan, where the portion of flysch is larger, not only with termination of the cycle of sedimentation but in places the flysch of Turonian age is particularly thick. Superimposed synclinorii affected by intense folding are manifested there in structure.

f) Late tectonic flysch — paraflysch in the sense of L. R. Contescu (1964) has formed in inner early depressions on longitudinal synclines originated by Cretaceous folding. Flysch s. s. is predominantly concerned (Lutetian—Priabonian) accompanied by complexes of carbonate molasse in the substratum and near the margins. Later folding affected this flysch to a lesser degree only. Its prototype is the Central Carpathian flysch. There are slight, flat folds, even rare in the southern zones, where the flysch character is disappearing. Compressional movements are mainly manifested by backward reverse faults of southern vergency. Towards the Outer Flysch Carpathians, to which the post-tectonic flysch basins form the hinterland, refolding of flysch and its stratigraphic range (Upper Cretaceous—Oligocene) enlarge. Analogous, more varied in the content and of larger stratigraphic range, is also the Transcarpathian flysch in the East Carpathians. The tectonic affect of the described type flysch diminishes in inward direction, thus from the Flysch zone of the Outer Carpathians, with which it is connected not only in paleogeography but also tectonically. It is a flysch attached to the Flysch zone of the Outer Carpathians, more or less with the rebound of folding only. In many aspects is also analogous the flysch of the Ostreni Basin in the Albanides connected with the thick flysch of the Krasta zone.

g) Also when not abundantly, in the Alpides, mainly in the Triassic but also in the Jurassic also flysch facies as inter-links of limestones sequences, so called pseudoflysch (L. R. Contescu 1964) are found. They were folded out later, i. e. together with underlying and overlying limestone facies. An example is the Lower Carnian Lunz Member in the Choč nappe of the West Carpathians and / or Anisian flysch in the Budva unit in the Dinarides (B. Čirič 1963), Upper Triassic flysch in the Kotel zone of the Balkan, Lower Doggerian flysch in the Klippen Belt of the West Carpathians. Such flysches are bound to the zones most active tectonically. In many cases there is not a "subordinate" facies but to a considerable extent controlling the character of a partial unit. For instance, in the West Carpathians the Lunz Member is characteristic of the Biely Váh partial unit of the Choč nappe, having displayed the character of a trough active tectonically in the Triassic. Such flysch facies represent strange inter-links amidst limestone formations and form the base for vertical division of units, their splitting into partial units-slices. The Choč unit of the West Carpathians provides a sufficient number of examples in this regard.

Spatial Distribution of Individual Flysch Types in the Alpides

Representation of flysch facies generally and of the individual paleotectonic and geotectonic types and their distribution are different in the individual segments of the Alpides. It may be said that each segment has its arrangement of flysch characteristic of it, indicating certain particularities of development. The changes and connections of individual types of flysch units in longitudinal direction may serve for consideration of genetic relations and differences between the individual segments of the Alpides.

Eastern Alps

Distinct by a little representation of diastrophic facies in the more inner zones. A partly flysch character displays the Lunz Member — Lower Carnian — in the Lunz nappe. The pre-orogenic flysch is represented only by the Albian—Cenomanian in the northernmost nappes of the Oberostalpin, in the Frankenfels nappe — the easternmost segment; it terminates the cycle of sedimentation (starting as early as the Permian) and continues from the underlying marlstone-limestone Neocomian complex. A particularity of this flysch are thick conglomerate layers with exotic material. In the more southern Lunz nappe detrital Cenomanian occurs only scarcely, in transgressive discordant position (B. Plöchinger 1960). Other inner units in the eastern segment do not show any diastrophic facies. It is remarkable that in the western section of the Eastern

Alps, in the Grisonides on the territory of Switzerland, where Cretaceous folding was more gentle, diastrophic facies-predecessors of folding are known not only in the Oberostalpin (thick Albian—Cenomanian silty shales with sandstone banks) but also in the Unterostalpin. The Lower Cretaceous already shows pre-flysch facies (argillites, marly shales with lenticles of grained limestones and polygenic breccias) followed by flysch and cryptoflysch facies of marly limestones and marls of Cenomanian age (R. Trümpy 1970).

With a smaller portion also the intraorogenic type of flysch (Paleocene) is represented in the Calc Alps, mostly represented by variegated marlstones of the cryptoflysch terminating (Paleocene) the Upper Cretaceous complex of facies, partly of molasse as well as limestone character of the so called Gosau type Cretaceous, lying discordantly on Cretaceous units but "adopted" to them by Early Paleogene folding.

The main representative of diastrophic facies of the Eastern Alps is the Flysch zone, relatively narrow, however, covered by the inner units in its larger part. As to paleotectonics, it represents a dissected flysch trough (flysch geosyncline) having appeared to the end of the Jurassic and the beginning of the Cretaceous and persisting as late as the Earlier Paleogene. The latest member in the western part is Paleocene, in the eastern part, in the Wienerwald, Middle Eocene, and in the Helveticum Upper Eocene (S. Prey 1968). The variety in facies is smaller in relation to the Flysch zone of the West Carpathians, with which it is connected. The whole complex starts with marlstone flysch (Tithonian—Lower Neocomian); flysch s. s. with thicker sandstones in the Cenomanian, Maastrichtian and Upper Paleocene is predominating; however, the sandstones are not manifested in structure more distinctly. The variegated facies of the cryptoflysch are mainly the so called Buntenserie (Upper Cretaceous-Paleocene) of the Gresten Klippen zone. In the Upper Cretaceous and Paleocene we may record migration of the axis of the flysch trough to the north. A difference more distinct in contrast to the Carpathians is the lacking linking of the flysch trough with the fore-deep filled up with molasse (the molasse trough started to appear to the end of the Upper Eocene). Linking with the pre-flysch substratum is unknown.

In western direction, in the Alps of Switzerland, the Flysch zone is represented by several flysch complexes connected with the basement of the individual partial zones of the Penninicum folded out by Early Paleogene (Pyreneic) folding (R. Trümpy et al 1970). The southernmost Briançon zone has a thick cryptoflysch representing the Upper Cretaceous from the Turonian as late as the Upper Paleocene, the flysch reaches until the Lower Eocene. A more distinct flysch trough is represented by the Valais zone, where the facies of schistes lustrées, thousand of metres thick, in essentials with marks of flyschoid (mostly metamorphosed shales, partly sandy, with breccias — Doggerian; shales with radiolarites and pelagic limestones — Malmian, shales and ophiolites — Lower to Middle Cretaceuos) passes trough the pre-flysch facies (shales, sandstones, limestones, polygenic breccias without regular schistosity) to the flysch of Upper Cretaceous to Upper Paleocene age up to several thousands of metres thick Vorarlberg, Unter-Engadin, Prätigau). The Helvetides situated more northerly have also their flysch, of sandstone character, Upper Priabonian—Lower Oligocene in age (more or less detached from the substratum) — predecessor of Early Neogene folding.

The West Carpathians

are characteristic not only in a considerable extension of flysch complexes but also in representation of practically all geotectonic types, with a great facies and paleotectonic variability. The distribution of flysch complexes is just one of the consequences of bipartily of the West Carpathians, with the Inner and Outer Carpathians.

In the Inner Carpathians the flysch complexes are only of accompanying character, making the palette of formations more or less variegated. However, noteworthy is the geotectonic variety of flysch. A flysch facies is displayed by the Lower Carnian Lunz Member in the Choč nappe, which in accompaniment of cherty nodular limestones (Upper Anisian—Ladinian) of Reifling type points at a narrow trough, active tectonically, short-dated. The flysch and flyschoid facies of pre-orogenic flysch terminate the cycle of sedimentation of the Krížna nappe (Albian—Cenomanian) and of the Tatride units (Albian--Cenomanian, in the High Tatra up to the Turonian), the flysch character with increasing sandstones is particularly distinct in the uppermost layers. Noteworthy are the layers of conglomerates with material of pebbles not only from the underlying Mesozoic but also from the crystalline basement (known from the Tatride units but also from the Krížna nappe — M. M a h e ľ 1967). In the Tatride unit interruptions of sedimentation have been found in places at the contact of flyschoid complexes with the limestone substratum. Surely it is noteworthy that in more southern units of Oberostalpinicum type pre-orogenic flysch is absent like also in the Eastern Alps.

Neither intra-orogenic flysch facies are absent in the West Carpathians. However, they are only known from the SW spur, continuing from the Gosau development of the Upper Cretaceous, in the Brezová Depression adjacent to the Klippen Belt. Also here they are accompanying a variegated palette of facies and filling up (also when refolded alone) synclinorii superimposed on Cretaceous units.

A feature characteristic of the Inner West Carpathians, however is a thick late-tectonic (Lutetian—Lower Oligocene) slightly folded flysch, filling up inner depressions, i. e. two zones of dissected synclinorii.

In the Klippen Belt we encounter a heterogeneous flysch, genetically connected with several foldings, variegated in facies and paleotectonically, with abundant representation of coarse flysch, also wildflysch and cryptoflysch beside flysch s. s.

The frame of the Outer Carpathians is formed by the mighty Flysch zone, a large dissected geosyncline extending from the Eastern Alps to the East Carpathians. In the Carpathians section in contrast to the Eastern Alps) beside the great width and thickness of the flysch complexes (up to 5000 m) the stratigraphic range (Tithonian—Oligocene), displacement of the trough axis outwards in late stages — or sedimentological polarity and considerably variety in facies of the flysch complexes are characteristic of it (Zd. R o t h in T. B u d a y et al. 1967). In the Lower Cretaceous the type of marlstone flysch and of black aleuritic cryptoflysch is predominating. In the Upper Cretaceous, however, dissection is much greater, beside flysch s. s. there are thick complexes of sandy flysch but also variegated cryptoflysch; they are distinctly manifested in dissection of the flysch geosyncline into cordilleras. In the Paleogene heterogeneity of facies also continues, however, there is a dissection in a smaller scale, with less differences in facies with rapid changes under general similarity of facies. The situation changed in the Priabonian so that the Oligocene is characterized by a relatively considerable homogeneity of facies, first with flysch s. s., later with sandy flysch with transition into flyschoid to molasse. The connection of flysch facies with molasse ones also in vertical direction and spatial connection of the flysch geosyncline with the fore-deep is immediate.

Hungarian Midmountains

The Inner Carpathians are linked with the Hungarian Midmountains showing several particularities also in representation of diastrophic facies. In the first place their small portion in relation to the Alpide segments is conspicuous; mainly the lack of flysch facies in pre-orogenic periods or pseudoflysch. The pre-orogenic Cretaceous flysch is also lacking, also when the cycle of sedimentation of Mesozoic (Permian—Lower Cretaceous) sequences terminates with detrital sediments as a rule. A certain tendency to diastrophism indicates only the Valangianian complex in the Gerecse Mts. (J. Fülöp 1961). Neither Upper Cretaceous sediments, predominantly coarse detrital and reef limestones — of Gosau type have accompaniment of flysch. A curiosity of the Hungarian Midmountains, however, is the Senonian—Eocene (Lower Oligocene?) Szolnok flysch central trough, affected probably by Savian folding (K. Balogh, L. Körössy 1968), putting forward much surmise by its position between the Hungarian Midmountains and the Apusins.

The Apusins

are often considered as continuation of the Inner Carpathians; in representation of diastrophic facies they approach them in the presence of Lower Cretaceous pre-orogenic flyschoid complexes in the Codru nappe and of Upper Aptian—Cenomanian ones in the Bihor autochthon (M. Bleahu, D. Patrulius et all 1967). From the SW side they are bordered by a trough with heterogeneous flysch (see fig. 1) affected by Mesocretaceous as well as Early Paleogene folding, extending in direction diagonal to the axis of the Early Alpine geosyncline without closer genetic linking.

East Carpathians

A particular morpho-structural but also genetically different segment of the Carpathians extends easterly of the Strij-Latorica Fault Line. The Klippen Belt and its accompaniment of the Central Carpathian Flysch terminate here gradually and more northerly the Marmaroš Massif begins, accompanied by the group of the Bukovinian and Transylvanian nappes. No other area of the Alpides is equal to the area under consideration in the abundance of wildflysch to paramolasse and that in the position of pre-orogenic (prior to the Cretaceous folding) and inter-orogenic one (between the Cretaceous and Early Paleogene folding). In the group of the Bukovinian nappes there is a thick pre-orogenic Barremian—Albian flysch with abundant wildflysch facies and basic volcanics and with olistholiths of limestones, derived from the fronts of moving nappes of the Transylvanian group. The distinct Cretaceous diastrophism is accompanied by thick conglomerates of the Bucegi type (1500—2000 m); some authors consider it as paramolasse (L. R. Contescu 1968), others as wildflysch because of diastrophic layers (G. Murgeanu, M. Filipescu 1961). A type analogous of conglomerates Vraconian—Cenomanian in age transgressively and discordantly overlaps the Hagimas nappe and the Bukovinian nappes (M. Sandulescu 1967).

Another feature specific of the East Carpathians is the mighty flysch trough at the boundary of the Inner and Outer Carpathians, mainly filled up with a thick flysch Tithonian to Albian in age, especially with marlstone flysch of the Sinaia Beds with detrital material increasing in the Aptian and Albian (J. Dumitrescu et al 1962). An evidence of the deep foundation of trough is the presence of basic rocks. The second, inter-orogenic cycle with less representation of flysch facies, accompanied by crypto-flysch and wildflysch, forms the upper stage of this trough, from which the nappes of Ceahlau and Baraolt were folded out, probably during the Early Paleogene folding (M. Sandulescu 1971).

Several particularities displays also the Flysch zone of the East Carpathians with distinct orogenic polarity and vertical as well as lateral linking with the molasse. Among the particularities should be included the mighty development of Lower Cretaceous flysch in aleuritic (black) flysch type in the Audia and Macla Zagon unit and flysch s. s. with euxinic facies in the Curbicortale unit; the mighty development of sandy flysch mainly Paleogene in age (Tarcau Sandstones up to 2000 m thick) in the Tarcau nappe. The northernmost unite — Marginale unit shows a particularity in representation of limestones and conglomerates amidst flysch sequences (Eocene—Oligocene — J. Dumitrescu et al 1962).

The South Carpathians

provide a quite different picture in distribution of flysch. The externide Flysch zone gradually disappears in them and the flysch is concentrated in a trough situated between the more inner and outer units. This Severin-Kraina trough also began in the Tithonian, persisted in the period of the Lower Cretaceous (Al. Codarcea, Raileanu et al 1961), only in more southern areas on the territory of Bulgaria in the unit called Kraina flysches also appear in the Upper Cretaceous, even in the Ypressian and Lutetian, however, separated by interruptions of sedimentation (in the Upper Cenomanian and Danian).

In the group of pre-orogenic flysches also flyschoid sandstone-claystone complexes may be included, accomplishing the cycle of carbonate sedimentation of the Getic nappe to the end of the Aptian.

In the Outer units of the South Carpathians there are thick complexes of coarse-detrital Turonian—Senonian sandy flysch (flysch of Mehedinti) or with considerable portion of conglomerates (d'Aržana Flysch) (Al. Codarcea, Railleanu 1961). This flysch may be also characterized as inter-orogenic, however, more linked with the limestone substratum structurally as the Mesocretaceous folding was more gentle in these areas and the main creator of the tectonic units were Early Paleogene movements.

In the inner units affected by intensive Cretaceous folding the Upper Cretaceous complexes, Cenomanian—Turonian in age (detrital facies with abundant sandstones and conglomerates as well as coral limestones) display the character of pseudomolasse. However, even a smaller portion of flysch facies or marlstone ones with the tendency to flysch is not lacking (Nadanova Beds).

A particular position represents a mighty trough of the type of superimposed linear graben at the boundary of inner and outer units — the Timok graben. Its specific feature is a variegated sedimentary-volcanogenic complex up to 3000 m thick (stratigraphic range Cenomanian to Danian) with brackish-lagoonal facies including coal seams, bituminous shales and sandstones; shallow-water detrital and organogenic limestones, a plenty of extrusive volcanics, andesites, tuffs, agglomerates and dacites, with abundant porphyrite andesite dykes. A considerable part is also represented by cryptoflysch facies of couches rouges and also flysch (P. Stefanovič, M. Andelkovič, A. Grubič et al 1967) but only as one of the facies of this volcanogenic-sedimentary formation varied genetically.

Balkan

Very distinct features in distribution of diastrophic facies shows the Balkan, in which in the first place the lack of distinct externides with predominating flysch and molasse fore-deep is to emphasize. The Flysch zone, more distinct morpho-structurally, is represented by the Luda Kamchiya zone in the eastern part of the Balkan at the boundary of the inner and outer zones. Of considerable importance in the structure is the Tithonian-Berriasian as well as Upper Cretaceous flysch linked with the volcanogenic-sedimentary formation.

In the Balkan the onset of flysch in extensive flysch trough also started in the Tithonian. In the more southern unit, Strandža, the flyschoid complex of black claystones with intercalations of marmorized limestones and layers of diabases terminates the predominantly carbone sequence prior to the Early Cretaceous folding (E. Bončev 1966).

A mighty flysch is characteristic of the Balkan, mainly its central block westerly of the Jablonica Line. According to I. K. Načev (1969) the so called Niž-Trojan partial geosyncline is concerned, extending from the eastern border of the Serbian-Macedonian Massif following the northern margin of the Rhodope Massif along the Balkan, about 500 km long and up to 130 km wide. Thickness of flysch attains up to 3000 m and beside predominantly fine rhytmical flysch also subflysch and even wildflysch take part in it. Remarkable is the short duration (Tithonian to Berriasian) as well as the position of flysch in stratigraphic sequence. The flysch develops suddenly from carbonates of the Kelloway—Kimmeridgian complex. However, in places the development is gradual from leptogeosynclinal members including radiolarites with the presence of a thin layer of pre-flysch (oral communication of I. K. Načev). The carbonate-terrigenous formations replace the flysch also in its overlier, mainly situated in the northern parts of the flysch trough, at the southern margins of the adjacent more northern Moesian platform. These complexes overlying the flysch are considered by I. K. Načev (1969) as a formation of the lower marine molasse filling up the fore-deep linked with the flysch geosyncline in the time of northward migration of the axis. The inner depression should be represented by Albian (?)—Cenomanian inner basins bordered by faults of linear arrangement in the southern parts of the flysch geosyncline, filled up with a coal-bearing terrigenous formation — the upper molasse.

A particular structural position display the flysch complexes in the Srednogorie zone. Flysch is filling up synclinorii there in accompaniment of the Upper Cretaceous variegated volcanogenic-sedimentary formation replacing laterally the effusive-porphyric formation (andesite- latite). Especially thick is the flysch in the synclinorii of Burgas and Surna Gora, not only in the upper layers (Maastrichtian—Danian) but in places also in the Turonian, thus in the lower parts of the variegated and changeable formation; representation of flysch is essentially higher compared to the Timok Graben. This flysch is a part of the inner-orogenic type.

The more northern flysch trough of the Luda Kamchiya unit (Emin Depression of I. K. Načev 1969) separated by the narrow zone bult up of older formations of the Srednogorje starts with conglomerates. Its essential part is represented by a predominantly marlstone-flysch thousand of metres thick (Turonian—Paleocene). The higher complex with sandstones predominating (Ypressian—Lutetian) but with conglomerates of wildflysch type is considered by some authors as the upper horizon of the flysch geosyncline (E. Bončev 1966), by others as already the lower molasse, a part of the extensive fore-deep reaching also the Fore-Balkan (I. K. Načev 1969). This later-flysch and / or flyschoid formation precedes the Pyreneic folding involving a change in development of the Balkan, the onset of formation of frequently transversely oriented inner basins with typical molasse. From the standpoint of paleotectonics the Luda Kamchiya zone represents a trough founded in the period of Cretaceous folding and terminated by Late Illyrian or Pyreneic folding. Interruptions of sedimentation between the Turonian and Senonian and after the Paleocene are only manifestations of the individual acts of Cretaceous folding and earlier manifestations of Early Paleogene folding.

The narrow Kotel zone situated more northerly of the mighty Luda Kamchiya Flysch zone resembles the Klippen Belt of the Carpathians in its structural character; it displays flysch facies (marlstone flysch with wildflysch and olistholiths) in the Norian and aspide to flysch facies of argillites with layers of quartzites and brecciated conglomerates in the Doggerian. The envelope of these klippes is formed partly by Upper Cretaceous marlstone flysch (Cenomanian to Senonian), partly (mainly in the northern part) by the Upper Cretaceous in more northern, platform development.

Dinarides and Albano-Helenides

Characteristic by an especially great representation of flysch are the Dinarides and Albano-Helenides, with considerable variety of paleotectonic and geotectonic types of flysch. Thicker flysch facies we encounter also amidst older carbonate sequences, marlstone flysch in the Anisian (Budva) up to 2000 m thick and variegated flysch, partly volcanogenic in the Jurassic of the ophiolite zone (B. Čirič 1963). In both cases units with higher sea-floor dynamics are concerned. The essential part of the flysch in the Dinarides and Albano-Helenides is of pre-orogenic flysch character, terminating the cycle of sedimentation of units prior to their folding. Characteristic of the Dinarides and Albano-Helenides is a polarity of folding with gradual migration of the axis from the inner towards the outer units (B. Sikošek, W. Medwenitsch 1965, Aubuoin J., J. Ndojaj 1964). As a consequence of that also the flysches are becoming younger and younger from the inner part in outward direction in essentials. In the innermost units there is partly flysch s. s., partly sandstone flysch developing trough a layer of globotruncan marlstones and marly limestones (200—300 m) from thick organogenic and organodetrital Upper Cretaceous limestones. These, however, are usually resting discordantly an earlier Mesozoic substratum. The Maastrichtian—Danian, in places perhaps also Lower Eocene flysch this way represents termination of the second cycle of sedimentation, the inter-orogenic cycle formed between the Mesocretaceous and Early Paleogene folding. As the Cretaceous folding was gentle, however, it represents a part of the inner units (B. Sikošek, A. Grubič, B. Čirič et al 1967).

More westerly near the eastern margin of the Vysoki Krš unit the so called Durmitor Flysch, partly a claystone-sandstone flysch with layers of organodetrital limestones, corresponds to the Maastrichtian—Danian (B. Sikošek, W. Medwenitsch 1965). In the Albanian Alps, known as Vermosh Flysch, 500—700 m thick, it corresponds to the Maastrichtian—Lower Eocene (T. Bicoku, A. Papa 1970). In the Vysoki Krš discordantly above the flysch facies the molassoid Promina Formation is found with predominating conglomerates, calcarenites and limestones. It is late-tectonic in the more frontal part partly also with facies of flyschoid character — Upper Eocene—Lower Oligocene in age. Near the outer frontal part of the Vysoki Krš unit the limestones reach as late as the upper part of the Lower Eocene, followed by flysch Dalmatian with layers of limestones. In the Budva unit varied in facies and tectonically already the Upper Cretaceous (Campanian—Maastrichtian) is of cryptoflysch development (couches-rouges) whereas the Upper Masstrichtian to Eocene is represented by a flysch variegated in facies. In southern continuation in the Cukali and Pindos units in the Albano-Helenides (T. Bicoku, A. Papa et all 1970. J. Aubuoin, J. Ndojaj 1964) the flysch started as early as the Maastrichtian and reached the Upper Eocene, in places in the Pindos zone probably as late as the Lower Oligocene. In the northern part it is known as the Krasta Flysch more than 1000 m thick. In the lower part it is terrigenous-carbonate; sandstones and claystones alternate with nummulite limestones. Near the cordilleras conglomerates are abundant, however, also variegated and pink marls are frequent. In the middle part wildflysch is abundant organodetrital limestones and conglomerates, also limestone olistholiths (Lutetian). In the upper part sandstone coarse flysch is predominating; argillites form only thin intercalations (Priabonian). However, changes in the type of flysch are not only in vertical but also in longitudinal direction of the unit. In the northernmost part of Albania the so called Xani Flysch is known with aleurites, claystones and marls predominating, thus an aleurite to marlstone-limestone flysch Maastrichtian—Eocene in age.

In the Dalmatian zone usually flysch s. s. with layers of organogenic and organo-detrital limestones termed as Dalmatian type by us develops from Eocene nummulite limestones at the beginning of the Upper Eocene. It reaches as late as the Upper Oligocene. In more southern continuation, in the Kruja and Gavrovo zones there is mostly a sandstone flysch Priabonian—Oligocene in age with layers of conglomerates and olistholiths of limestones.

In the outermost Ionian zone a flysch relatively thick starts with the Upper Eocene and reaches as late as the lowermost Miocene; it is linked through the Lower Helvetian schlier with the superimposed fore-deep-preceding the folding having taken place after the Lower Helvetian (J. Aubouin, J. Ndojaj 1964). In essentials there is a fine rhytmical flysch with two components, in the Oligocene with increasing amount of coarser sandstones. Near the outer margin adjacent to the outermost unit of sill type without flysch — the Sazani unit, limestones are predominating in the flysch.

Owing to thickness as well as the wide stratigraphic diapason, mainly in the Cukali zone, some of the mentioned pre-orogenic types of flysch represent a deep, dissected trough in the proper sense of word. Of a type particular are other two troughs in the Dinarides. In the wide zone of the Durmitor Flysch a Lower Cretaceous flysch thrust on the Upper Cretaceous flysch in the time of the Early Paleogene folding was found in the last years, folded out from a narrow trough situated at the boundary of the inner and outer Dinaride units, described as the so called Bosniak unit. With its southern promontories it reaches as far as the Albanides (R. Blanchet, J. P. Cadet, J. Charvet, J. P. Rampnoux 1969). Starting with the Tithonian or Berriasian it reaches as late as the Aptian, possibly also the Cenomanian in places. In essentials there is a pelitic sandstone flysch with layers of fine-grained limestones, often with cherts. In higher layers the amount of sandstones and micro-brecciated limestones increase. An analogous flysch is lying transgressively on the ophiolite Mirdita zone (Dodoma, Mello 1967). The substratum of the Tithonian flysch of the Bosniak unit is formed, by the diabase-cherty formation of the Jurassic; the position of flysch is transgressive.

An extensive flysch trough of particular type split into several subsparallel zones with different development is the Vardar zone near the eastern margin of the Dinarides (B. Ćirić 1963). The flysch forms two cycles: a Tithonian—Lower Cretaceous and

Upper Cretaceous one, separated by discordance often accompanied by interruption, or molassoid, coarse detrital and limestone facies. The Tithonian—Lower Cretaceous flysch sometimes displays a character of an aleuritic flysch. The Cenomanian—Senonian flysch attains a thickness of up to 1000 m in places. More frequent are also manifestation of volcanism, in the lower as well as upper cycle.

In the NW part at the boundary of the inner Dinaride units and the Vardar zone a thick flysch known as the Majevica Flysch is developed. It starts with the Lower Eocene and passes into molasse in the Lower Oligocene. It is only slightly affected by folding. We may range it to the type of late-tectonic types affected by folding fading out only. It represents the basal filling of the hinterland depression (B. Čirič 1963).

A typical inter-orogenic flysch is the flysch in the Horst-Graben zone accompanying variegated complexes of alternating various types of facies: grey marls, dark-coloured claystones, sandstones, rudist limestones, conglomerates grouped into two cycles: the Cenomanian—Turonian and Upper Turonian—Senonian one. The flysch and flyschoid are abundant, mainly in the Senonian (southerly of the Babia Gora Mts.).

Conclusions

Following of distribution of the flysch and its types in the individual tectonic units of the Eastern Alps, West Carpathians, Balkan, Dinarides and Albano-Helenides provides us the possibility to express some conclusions.

1. The flysch facies occurring amidst predominantly limestone sequences of the Triassic and Jurassic (in the Anisian, Carnian, Liassic and Doggerian) are bound to units folded out from narrow troughs, manifested in a more dynamic type of sediments. The occurrence of the flysch in them should be considered as evidence of this dynamics.

2. The thickest flysches as well as those most variegated in facies have formed in longitudinal troughs. They have usually a wider stratigraphic range than the preorogenic flysch in adjacent units, from which they also differ in more thickness and variety. Such trough originated most abundantly as early as the Tithonian or Berriasian (Flysch zone of the Eastern Alps and Carpathians, Ceahlau-Severin-Krajina zone, Niž-Trojan trough in the Balkan, Vardar zone, Bosniak zone). In the most of them the tectonic units formed as late as the Early Paleogene folding, even in the time of the Early Neogene folding in the Flysch zone of the Carpathians.

Other troughs formed already in the Middle Cretaceous; the Luda Kamchiya and / or the Budva-Cukali-Pindos in the Upper Cretaceous.

In some troughs after initial intense sedimentation (Niž-Trojan trough) dynamics was gradually diminishing; the flysch is replaced by detrital limestones.

In the majority of troughs the flysch starts with more pelitic, mainly marlstone-carbonate sediments, a marlstone — and / or aleuritic flysch; in hinger horizons the amount of coarser detrital rocks is increasing more and more.

The geotectonic position of troughs in the geosynclinal system is varied, however always at significant boundaries of blocks; they are evidently bound to deep-seated faults. The troughs are most abundant at the boundary of outer and inner zones (Bosniak, Luda Kamchiya, Ceahlau-Severin); others form own externide geosynclines (Flysch zone of the Carpathians), a particular type is the inner marginal syncline — the Vardar zone. The Mureš trough is situated in direction diagonal to the adjacent orogenic mountains of the Western Apusins; it differs from other ones in an essentially higher portion of volcanics.

In some cases the troughs are developed in the overlier as the upper parts of older troughs (Cukali in the Albano-Helenides, the Valais trough in the Western Alps) — in such cases the flysch sequences are usually linked with the foregoing trough filling — the pre-flysch facies. Other troughs develop as new structural forms (fig. 2).

3. Relation of flysch to the molasse is complicated. The period of the flysch is usually replaced by the molasse period. In areas with developed orogenic polarity the flysch of the outer units alternates with earlier molasses in the inner zones. Such molasses are usually discordant and affected by reflected movements and show indications of diastrophism (schlier, intercalations of flyschoid facies in the Oligocene to Helvetian of the Inner West Carpathians). In the outer units formed in the period of processes of foldings fading out in the neighbourhood of the platform the flysch passes into molasse in lateral as well as vertical direction. There is no immediately pre-orogenic flysch but the molasse facies often accomplish the cycle of sedimentation of the tectonic units (outer nappes of the Flysch zone in the Western and Eastern Carpathians). Where orogenetic polarity is less evident, linking of flysch with molasse disappears mainly in lateral distribution (western section of the Eastern Alps and Western Alps, South Carpathians).

4. The formations most variegated in facies with sedimentation least regular formed in the Upper Cretaceous in areas, where they represent intra-orogenic formations, thus formations originated in the period between the Cretaceous and Early Paleogene folding. The molasse facies are found together with cryptoflysch as well as flysch facies. The tendencies towards troughs are combined with early depressions of graben-like shape.

5. It is without doubt that the particularities among the types of flysch the late-orogenic flysch belongs. Remarkable in the Carpathians is its spatial and structural linking with the Klippen Belt, thus the zone of a deep-seated fault. In direction towards the Klippen Belt tectonic deformation of the flysch as well as ist stratigraphic range, its linking with the flysch geosyncline in general increase. With termination of the Klippen Belt in western as well as eastern direction also this type of flysch disappears. The Klippen Belt was evidently playing a part in the origin of this facies markedly progenetic in its character, however, corresponding to post-tectonic structures in its structural position.

6. In the Alpides a considerable extent falls to the flysch complexes, among which of particular importance are those folded out from troughs and for particular geosynclines. Characteristic of them is: frequent linking with the foregoing leptogeosynclinal sediments (with deepening); accompaniment by basic volcanics in the basal part; coincidence in time of foundation of the flysch trough with commencement of the first foldings in the Alpides in the Tithonian and the later ones in the Albian — Cenomanian, i. e. with the period of most intense deformations of the inner zones. These circumstances extended by inter-block position of flysch troughs, root-less nappes filded out from them, offer the idea to link them genetically with weakened zones, formed by intense basification. These views also result from comparison with old Pre-Carboniferous complexes, which are mostly of flysch and aspide type.

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