СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО, год. XLII, кн. 2, 1981
REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY, vol. XLII, part 2, 1981

Проблем IX. Геосинклинальный процесс и становление земной коры

Problems of the Origin of Flysch in Bulgaria

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И. К. Начев — Проблеми на флишеобразуването в България. Флишките ритми, пачки и геокомплекси имат дискретно разпределение в пространството и времето. Пелитните скали са фонови. Кластичните скали са обусловени от наложена екстракластична, интракластична и тефроидна седиментация, създала граувакavailability-алевролитен, кластично-варовиков и тефроиден флиш. Тефроидните скали са свързани с подводен вулканизъм и тефрова реседиментация. Палеотеченията от шелфа се спускали по каньони през склона и отлагали материала в подножия, батиални и абисални депресии. Реседиментацията се извършила от подводни свличания (олистостроми), плътни зърнести потоци (флуксотурбидити), суспензионни течения (турбидити и ламинити) и придънни течения (контурити). Флишеобразуването се реализирало в епиконтинентални и междудъгови трогове и в подножия на вътрешни и окрайни морета и океани през океански, преходен и континентален етап в еволюцията на литосферата.

The Studies of the Hercynian and Alpine flysch in Bulgaria and the comparative data on the flysch in the Carpathians, Crimea and Caucasus enable some statements and conclusions on the features, morphology and origin of flysch to be made. Some problems of the origin of flysch are discussed below (Nachev et al., 1980).

Flysch bodies

Flysch associations, as geologic bodies, have different (fig. 1) forms and dimensions. The rhythms are elementary and real flysch bodies in nature. They exibit a regular and repeated rhythmical alternation of layers (beds) of clastic and pelitic rocks. The real in composition rhythms are composed (fig. 2) of: (1) greywacke (sandstones) — siltstones — shales (or marls); (2) clastic limestones with arenitic and siltic texture — limestones — marls; (3) tephroidal rocks with ruditic, arenitic and siltic texture — marls — argillaceous limestones. The thickness of rhythms is mainly up to 1 m, in average from 0.1 to 0.7 m. The flysch rhythms have a complex of diagnostic features (Dzułynski, Smith, 1964; Начев, 1970). The lack of these features indicates a normal nonflysch alternation of different rock types.

The packets comprise many rhythms with composition and structure of same type. Their thickness is up to several hundreds of meters (fig. 2).

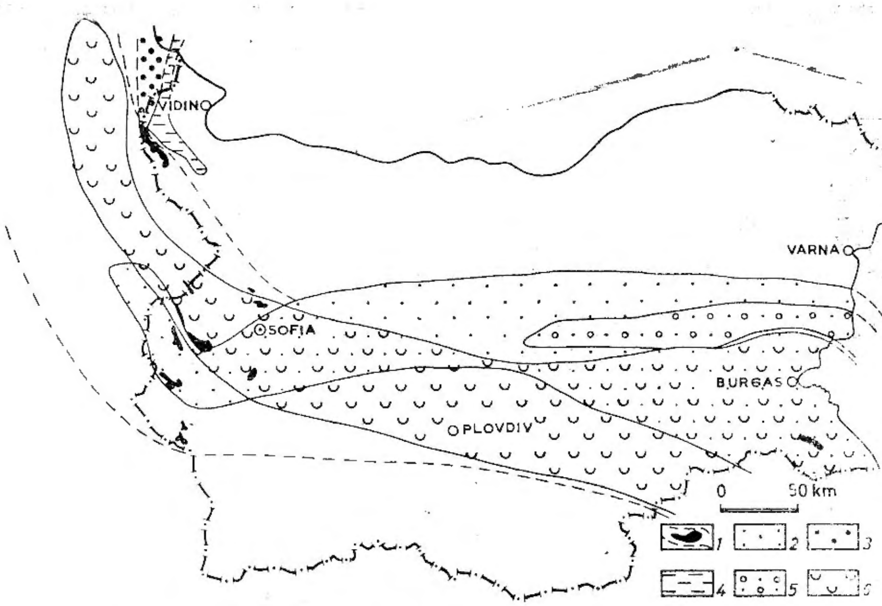

Fig. 1. Sketch of Occurrence of the Flysch in Bulgaria

1 — Kuchai-Chernogorie flysch (Middle Devonian — Lower Carbonian); 2 — Nish-Troyan flysch (Tithonian, Berriasian); 3 — Kraina flysch (Berriasian — Barremian); 4 — Koula flysch (Turonian — Maastrichtian); 5 — Emine flysch (Turonian — Paleocene); 6 — flysch packets in the Srednogorie zone (Coniacian — Campanian)

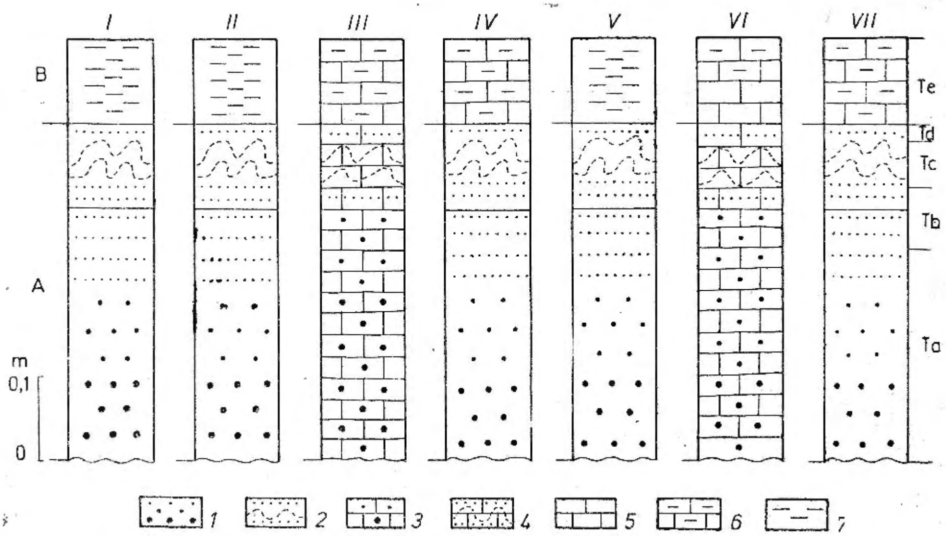

Fig. 2. Rhythmes of the Types of Flysch

1 — graywackes; 2 — siltstones; 3 — arenitic clastic limestones; 4 — siltic clastic limestones; 5 — limestones; 6 — marls; 7 — shals; A — clastic rocks; B — pelitic rocks; structural intervals: Ta — graded bedding; Tb — lower parallel lamination; Tc — cross-lamination and convolution; Td — upper parallel lamination; Te — pelitic interval; I — Kuchai-Chernogorie graywacke-siltstone flysch; II — Nish-Troyan graywacke-siltstone flysch; III — Krayna graywacke-siltstone flysch; IV — Kraina clastic-limestone flysch; V — Koula graywacke-siltsone flysch; VI — Emine graywacke-siltstone flysch; VII — Emine clastic-limestone flysch

The large real flysch bodies with thickness of hundreds to thousands of meters are considered as geocomplexes ("sedimentary associations"). They have likewise a composition and structure of same type, rarely are of mixed composition. In vertical direction they begin with pre-flysch, then follows flysch and terminate with subflysch (Н а ч е в, 1973, 1974, 1976). In lateral direction they show a symmetric or assymmetric pattern (Figs. 1, 2).

Flysch bodies have different genetic predestination. Flysch geocomplexes are widespread and originated in large, linear and deep troughs (basins). Flysch rhythms and packets (deep-sea fans) occur in individual environments of the basins and are probably specific for continental raises, foots of volcanoes, etc.

Flysch in space

Flysch has been found in most mountain chains. This leads to the conclusion that flysch is characteristic of "folded orogenic belts" and originated in "geosyncline-orogenic zones". In mountain chains flysch does not form single geologic bodies, for instance "flysch in the Alpine folded area" (А р х и п о в, 1971, 1973, 1974). This is a system of real in nature but discrete in space geologic bodies. In the Alpine zone there are many individual and isolated in space flysch bodies but not a single "Alpine flysch". In the "Alpine folded area" the occurrence of flysch is considered to be limited in "flysch troughs of different age" which were "superimposed on diverse geologic-structural basement and developed in different parts of the folded area" — "inner and outer tectonic zones" with "eu- and miogeosyncline regime" (А р х и п о в, 1974, p. 133).

The analysis of spatial distribution of flysch should take into account the differences in age, in composition and type, in structure and mainly the discrete character of the flysch geologic bodies in separate zones, segments, systems, areas and belts.

Data on the spatial distribution of flysch in Bulgaria show that Kuchai-Cherna gora Hercynian flysch, Nish-Troyan Early Alpine flysch, flysch packets in the Srednogorie and an Emine Late Alpine flysch in the Balkanides may be distinguished. The early Alpine Kraina and the Late Alpine Koula flysch are localized in the confines of the Carpathian folded area. The flysch in Bulgaria does not form a single geologic body but a system of geologic bodies of different age, isolated from each other and confined to different areas. The flysch bodies retain their discrete character (fig. 3) even by partial or complete superposition or coincidence in space.

Flysch in time

Flysch is developed in Caledonian, Hercynian and Alpine folded systems and is formed in different geotectonic cycles. Without any doubt the flysch is of different age and type. The problem of the age of flysch or of the vertical distribution (in time) is interesting and important. The analysis of the "chronology of flysch" leads to the conclusion that the "origination of flysch in the Alpine folded system is a prolonged and in fact continuous in time process (though very irregular in activity) which accompanied the whole development" (А р х и п о в, 1974, p. 133). It is assumed that the "activization of the process of flysch origination commonly began or terminated almost simultaneously in more or less wide spaces, i.e. had in a number of cases distinct and accurate age boundaries. Such boundaries in the Alpine folded area are the beginning of the Liassic and the end of the Middle Jurassic, the Tithonian age, the second half of the early Cretaceous epoch, the Senonian, the Eocene, the beginning of the Oligocene and the Lower Miocene. Naturally, the unequality of those boundaries should be taken into consideration as well as another important aspect — "the time-span between them was only a period of decrease but not a break in the processes of flysch origination in the confines of the whole Alpine folded area"

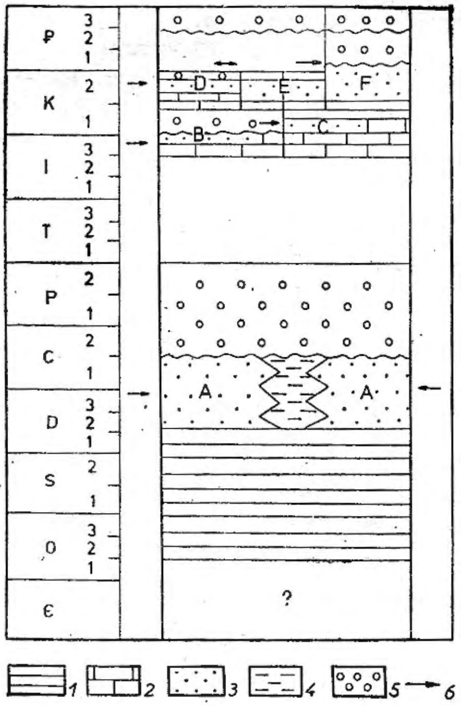

Fig. 3. Distribution of the Flysch in Bulgaria
1 — pelagic shals (slate); 2 — shallow-wather limestones; 3 — flysch; 4 — pelagic shals and limestones; 5 — molasse; 6 — sources of clasts; A — Kuchai-Chernogorie flysch; B — Nish-Troyan flysch; C — Kraina flysch; D — flysch packets in Srednogorie trough; E — Koula flysch; F — Emine flysch

From methodical viewpoint the conclusion for the "continuous in time process" of flysch origination is not acceptable and contradicts the data on the age of flysch and the chronology of flysch origination in the Alpine folded area and mainly in its separate systems, segments and troughs. The analysis of these data shows that in eight (from 18) regions the formation of flysch is a discontinuous in time process. In most of the other 10 regions, instead of a single abstract flysch, there are two or more real and concrete flysch bodies which are divided by non-flysch, mainly epicontinental shallow-water carbonate or other sedimentary geocomplexes. For instance in the Great Caucasus, according to available data and author's studies, there are several flysch bodies of different age and type: clastic-limestone flysch (Upper Jurassic, Lower Cretaceous), greywacke-siltstone flysch (Lower Cretaceous), clastic-limestone flysch (Upper Cretaceous) and greywacke-siltstone flysch (Paleogene).

The data on the age of flysch in Bulgaria (fig. 3) lead to the conclusion that the origination of flysch is a process which is discontinuous (impermanent) in time. In the individual regions and troughs the formation of flysch began in different time: in the beginning of the Tithonian in the Nish-Troyan trough, during the Berriasian in the Kraina trough, in the beginning of the Turonian in the Koula trough, during the Late Turonian in the Emine trough and during the Coniacian in the Srednogorie zone. It terminated like-wise in different time: during the Berriasian in the Nish-Troyan, during the Barremian (?) in the Kraina, after the Maastrichtian in the Koula, during the Paleocene in the Emine trough and before the Maastrichtian in the Srednogorie. The troughs were spacially isolated and in them different types of flysch originated, i.e. the formation of flysch in them had different character. Consequently, the flysch bodies are discrete and the formation of flysch was a discontinuous in time process. The Alpine development of the Balkanides was accompanied by discontinuous and two-cyclic — early and late Alpine formation of flysch (Начев, 1973, 1974, 1976a, b, 1978; Nachev et al., 1980).

Flysch and synchronous volcanism

Flysch is usually regarded "as a typical non-volcanic geocomplex" (D z u - l y n s k i and S m i t h, 1964), as "miogeosyncline" (Б о н ч е в, 1971) of "mio-flysch" (C o n t e s c u, 1974) sequence.

Below flysch in thick pelagic sediments ("pre-flysch") few volcanic rocks have been found of the type of: "ophiolites" in the Pieninni zone, "teshenites" in the "Teshin beds" (K s i a z k i e w i c z e t a l., 1962) or basalts in Sinaia (C o- d a r c e a e t a l., 1965; S t e p h a n e s c u e t a l., 1979). In the presence of volcanic rocks in the basement the designation "eu-flysch" (C o n- t e s c u, 1974) is proposed.

Information on volcanism, synchronous with formation of flysch, is acarce. In the Dinarides, section Voluyak (Metochia), basic volcanics (diabases) have been found in Maastrichtian flysch. Depending on its character the synchronous volcanism determined "specific lithologic and textural changes in the flysch" such as "large land slides, lack of typical flysch sedimentary features, presence of volcanic matrix in the sediments and occurrence of siliceous rocks" (Йованович, 1965). "Such a flysch, altered by volcanism and with specific diagnostic characteristics is divided as a special type of flysch, the so-called volcanic flysch" (Й о в а н о в и ч, 1965, p. 113).

In Bulgaria, on the basis of composition and type of clastic rocks in flysch a tephroidal or tephro-turbidite flysch has been distinguished and described in detail (Н а ч е в, 1976a). The tephroidal flysch is casually determined by the manifestations of submarine volcanism and tephro-turbidite sedimentation. Information on the tephroidal flysch (inaccurate synonym "volcanic", "volcanotuffaceous" or "volcanogenic" flysch) is still incomplete (Й о в а - н о в и ч, 1965); Х в о р о в а и др., 1975, 1978; Н а ч е в, 1976a, 1978; Н а ч е в, С у л т а н о в, 1978, 1979; М а р к е в и ч, 1978; G a n e v a e t a l., 1978; N a c h e v, 1980).

The tephroidal flysch in the Srednogorie is an excellent example of Alpine flysch, related to the influence of a synchronous submarine and explosive andesite-basalt volcanism on the formation of flysch. However, volcanism is not directly generating flysch. The formation of the tephroidal flysch is determined by re-deposition, re-working and re-transportation of tephra by tephroturbidity currents with deposition on the foots of volcanic structures and in the depressions around them. On the hemipelagic clay-limestone sedimentation a tephroturbidite sedimentation is superimposed, combined with submarine slumps (tephro-olistostromes), deposition from turbidity currents (tephroturbidites) and from deep-sea bottom currents (tephrocontourites). The influence of the synchronous volcanism on the formation of flysch in the Srednogorie is indicated (fig. 1) by the presence in flysch of: (1) tephroidal rocks of ruditic to siltic-pelitic (ashy) texture, (2) volcano-hemogenic siliceous rocks (jaspers), manganese and iron rocks, (3) volcano-clastic rocks — tuffs and tuffites and (4) effusive rocks in the form of lava flows, commonly pillow lavas. The morphologic features of the tephroidal rocks, the mechanism of transport and their deposition have great importance in the interpretation of the role of volcanism in the processes of flysch origination. The tephroidal flysch and the tephroidal rocks are new genetic types and interesting natural phenomena. They are new in the sedimentologic literature.

Dynamics and mechanism of the formation of flysch

The formation of flysch is interpreted in different manner by the oscillation hypothesis (В а с с о е в и ч, 1951) and the turbidity current hypothesis (K u e n e n, 1958). The oscillation hypothesis overestimates the role of tectonic movements in the basins and sources (cordilleras) and explains the origination of flysch beds with the action of oscillation and change of conditions. According to the second hypothesis turbidity currents formed in the shalf and carried and sorted the material along canyons in the continental raise and deposited the latter in the trough (K u e n e n, 1958; Р о м а н о в с к и й, 1976).

Data on the present analogues of turbidity currents and turbidites in oceans contribute to understand and clarify the sedimentary processes which determine the formation of flysch. The formation of flysch is related to facies environments of deep-water or oceanic character. In those environments, under pelagic or hemipelagic conditions, a permanent sedimentation takes places and calcareous, clayey-calcareous (marl) or clayey (pelitic) sediments are formed. The clastic flysch rocks are related to superimposed sedimentary processes. Turbidity currents are the main factor and mechanism of transport and deposition of clastic material, and form turbidites (laminites) with gravity distribution of particles according to size (graded bedding), lamination, cross stratification and convolution as well as with diagnostic flysch structures. Other superimposed processes and mechanism of transport and deposition of clastic material are: submarine slumps — olistostromes; density currents — fluxoturbidites; deep-water bottom currents — contourites. The diagnostic features of these superimposed genetic types of rocks have great methodical importance to define the flysch as well as to distinguish flysch from rhythmic lower molasse.

Flysch and geodynamic environments

Oceanology indicates formation of contemporary turbidites in different geodynamic environments such as raises of mid-oceanic ridges, parts of oceanic plains, trenches, sedimentary terraces, inter-arc troughs, marginal seas, raises of continental slopes in oceans and marginal seas, inner seas, etc.

Undoubtedly flysch is formed in analogous paleogeodynamic environments. The recognition of those paleoenvironments is difficult. It should be based mainly on the concrete morphology, compositional and genetic features of flysch (N a c h e v, 1980). The origination of flysch took place in quite different paleo-geodynamic environments: (1) raises of mid-oceanic ridges; (2) oceanic plains; (3) raises of continental slopes in oceans; (4) raises of continental slopes in inter-arc troughs; (6) foots of volcanoes in inter-arc troughs; (7) back-arc epicontinental troughs, etc. (N a c h e v, 1980).

The origination of flysch in Bulgaria occurred at least in four types of geodynamic environments (figs. 1, 3): raises of continental slopes in a micro-ocean (marginal sea?) with oceanic substratum and basement of phyllite-shale ("aspide") and spilit-diabase geocomplex (the Hercynian Kuchai Cerna gora microocean); raises of continental slopes and volcanoes (the Srednogorie back-arc trough); deep-water epicontinental back-arc troughs (Nish-Troyan, Kraina, Koula and Emine trough). The back-arc troughs are the main paleogeodynamic environment of flysch origination in Bulgaria (N a c h e v, 1980). Paleomicro-oceans with formation of flysch posterior to ophiolitic geocomplexes plaid an important part in the Dinarides, the Vardar zone, Minor Caucasus, the Alps, in parts the Carpathians and elsewhere.

At the present state of flysch studies the processes of flysch origination are without grounds referred to one type, individualized "flysch basins", "flysch troughs" or "flysch geosynclines" (N a c h e v, 1969a, 1974; А р х и п о в, 1973, 1974; Р о м а н о в с к и й, 1976, etc.). The formation of flysch is a polifacies process. It should not be related to "flysch troughs", superimposed on different structures and parts which formed during "initial, middle and late stages" in the "geosyncline development of the Alpine folded system" (А р х и п о в, 1974). Evidently the formation of flysch is a natural phenomenon which is considerably more complex and diverse than the theoretical concepts and models suggest. The problem of flysch formation in different paleogeodynamic environments needs new and detailed investigations.

Flysch and tectonics

The relation of flysch formation and tectonic movements is an old, conflicting and controversial problem. Without any doubt tectonic movements were more active in the beginning, i.e. during the origination of troughs with flysch formation. They occurred as differentiated movements and had positive sign in the sources (cordileras, island-arcs, etc.) and negative — in the troughs. This mechanism of origination of troughs determined the vertical transition (pre-flysch) between non-flysch and flysch geocomplexes (Н а ч е в, 1974). Earthquake phenomena (seismicity) were an important factor in flysch formation which are still not well evaluated. Correlation of the formation of flysch with different paleogeodynamic environments indicates conditions of differentiated tectonic movements and different tectonic regime; spreading and ophiolite volcanism — in mid-oceanic ridges; subduction — in the trenches; extension, seismicity, subaqual volcanism and uplift of island arcs — in inter-arc troughs; uplift of the sources and subsidence of bottom — in the continental raises of oceans, marginal seas and epicontinental back-arc troughs.

The tectonic movements were activized considerably also during the termination of flysch formation and liquidation of the troughs. This occurred in parts synsedimentationally, but mainly during the liquidation of the troughs. This process took place at different time and in different manner. In some cases the flysch in the trough was folded in alpine-type folds, the flysch zones were uplifted and eroded and the lower molasses were deposited later and unconformably. In other cases flysch in the trough was alpine-type folded, the flysch zone was uplifted but the lower molasse basin was formed in inherited way and migrated centrifugally up to 100 km. In this case the mechanism of liquidation of troughs with flysch formation determined the occurrence of local (partial) vertical transition (subflysch) between the deep-sea flysch and the relatively shallow water rhythmic lower molasse.

The fact that flysch formation occurred in different paleogeodynamic environments is in contradiction to the statement about an accurately defined "flysch" stage of development. Evidently the attempts to correlate flysch formation with oceanic or "early geosyncline stage of initial subsidence", the transitional or "late geosyncline, pre-orogenic or middle stage", the continental or "late, orogenic stage" of development, are unsuccessful and pointless (B e r t r a n d, 1897; T r u m p y, 1960; K s i a z k i e w i c z e t a l., 1962; A u b o u i n, 1965; Х в о р о в а, 1961; N a c h e v, 1969b, 1974; J i p a, 1977 and others). It is obvious that flysch formation is a process which is characteristic not only of different paleogeodynamic environments but also of different evolution stages of the lithosphere.

Nature of basins with flysch formation

Flysch formation is a complex and discrete in space and time process. Its beginning is related to transformation of shallow-water basins into deep-sea troughs or with oceanic environments. Bathimetry of troughs was different but as a rule of deep sea type. The notations of bathimetry (K s i a z k i e w i c z, 1976) from "shallow water (150 m) to middle bathial (2 500 m)" should be supplemented with abyssal and oceanic environments. In troughs with depth larger than the crytical carbonate line, the facial or background sedimentation had pelitic (clayey) character. Hemipelagic limestones, argillaceous limestones or marls were deposited in troughs with a depth less than that of the carbonate crytical line. The transformation with gradual deepening of the troughs determined formation of pre-flysch (Н а ч е в, 1974). Later, the contourites of the pre-flysch were replaced by turbidites. Turbidite sedimentation was superimposed on the background pelagic, carbonate-lacking clayey or hemipelagic clayey-marly sedimentation. The character of turbidite sedimentation is determined by the composition of the clastic component in dependence of the source: graywacke at exogenic sources (dry lands) of granitoids or metamorphic rocks; extra- or intraclastic-limestone at carbonate composition of the source; tephroturbidite at synchronous explosive, subaqual volcanism and accumulation of tephra on volcanic cones. On the background sedimentation, processes of transport and deposition from submarine slumps were superimposed — olistostromes, from density currents — fluxoturbidites and from deep-sea bottom currents — contourites. The background and the superimposed sedimentation took place in different deep-sea geodynamic environments.

Obviously, the basins with flysch formation are paleogeodynamic environments of different type — oceanic continental raises and plains, trenches, inter-arc troughs, continental raises of marginal and inner seas and epicontinental back-arc troughs (N a c h e v, 1980). The concept of flysch formation in different paleogeodynamics environments deprives of content such trivial terms as "flysch basin", "flysch trough", "flysch facies", "flysch geosyncline", etc. Paleodynamic reconstructions of basins with formation of flysch are very difficult. The diagnostic morphologic and genetic features of the concrete flysch geocomplexes may be used as principal criteria to recognize the nature of basins with flysch formation of different type and to develop scientifically grounded models. Several models have been proposed to explain the evolution of basins with flysch formation. The Alpine model (B e r t r a n d, 1897), is based on extrageosynclines in the Alps. The cordillera-intrageosyncline model (K s i a z k i e w i c s, 1960) was created for the "flysch geosynclines" in the Carpathians. The Nish-Troyan model (N a c h e v, 1974, 1980) is based on the example of Tithonian-Berriasian flysch in Bulgaria. The Srednogorie model (Н а ч е в, 1976a, 1978) interpretes the influence of the explosive subaqual andesite-basalt volcanism in the formation of flysch and the role of tephroturbidite currents.

The problem of the nature of basins with flysch formation is subject to further studies since the models proposed do not reflect still the whole diversity of real basins with formation of flysch in the complex evolution of the lithosphere.

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(Постъпила на 19. XI. 1980 г.)