

Conditions for accumulation of coal-bearing formations in South-Eastern Europe during the Carboniferous

Katya Popova¹, Ivan Rusanov¹, Aleksandr Mogilev²

¹ Research Institute of Mineral Resources

1505 Sofia, bul. Kh. Kabakchiev, 23

² All-Union Geological Institute "A. P. Karpinski" (VSEGEI)

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К. Попова, И. Русанов, А. Могилев — Условия накопления угленосных формаций карбона в части Юго-Восточной Европы. На основании анализа расположения четырех крупных угольных бассейнов: Добруджанского и Свогенского в Болгарии и Донецкого и Львовско-Волинского в юго-западной части СССР, в региональных структурах Юго-Восточной Европы выведены общие закономерности развития условий осадконакопления в них на протяжении карбонового периода.

Установлена непосредственная связь общей для всех бассейнов регрессивной направленности тектонических движений с орогенным этапом развития варийских складчатых областей.

Особенно ярко эта связь выражается в западных частях изученного региона, в которых угленосные формации характеризуются большей полимиктностью состава терригенных пород, большей расчлененностью разрезов и увеличенным участием пирокластики в осадочных толщах.

Отмечены основные области-источники сноса. Так Украинский щит является главным источником сноса при накоплении угленосных толщ Донбасса и Львовско-Волинского бассейнов. Области сноса при образовании Свогенского бассейна были судетские горные обрамления межгорной котловины, а при формировании Добруджанского бассейна основным поставщиком терригенного материала был североболгарский свод, каледонские горы, расположенные с юга.

Характер седиментации в изученной области прибрежно-морской (Донбасс и Львовско-Волинский бассейны) и аллювиально-дельтовый, со всеми переходными типами (Свогенский и Добруджанский бассейны).

Abstract. Some general regularities of the evolution of sedimentation in the regional structures of South Eastern Europe during the Carboniferous have been derived by an analysis of the location of four large coal basins as the Dobrudzha and Svoege basins in Bulgaria and the Donetsk and Lvov-Volinsk ones in South-West USSR.

Direct relationship between the general regressive direction of tectonic movements and the orogenic stage of development of Variscan folded zones were established.

This relationship is best defined in the western parts of the studied region where the coal-bearing formations are characterized by more polymictic terrigenous rocks, better defined rock sequences and increased amounts of pyroclastics in the sediments.

The location of the main supply areas of deposited material was marked. Thus the Ukrainian shield represents the main source of deposition during the accumulation of coal-bearing of the Donbass and Lvov-Volinsk basin. The sources of deposition during the formation of the Svoege basin were the Sudet mountainous series of the intermountainous valley. The general supply of terrigenous material for the Dobrudzha basin was secured by the North-Bulgarian uplift of the Caledonian mountain located to the south.

The sedimentation character of the region studied is coastal (Donbass and Lvov-Volinsk basins) and alluvial-deltaic with all intermediate patterns (Svoege and Dobrudzha basins).

Introduction

On a global scale the process of formation of coal-bearing complexes during the Carboniferous is characterized by an extraordinary variety of regional tectonic settings and exogenic factors thus causing accumulation of polyfacies layers. For four years a group of specialists at the Research Institute of Mineral Resources in Sofia and the All-Union Geological Institute in Leningrad has been carrying out joint research in some large Carboniferous coal basins aiming at establishing the regularities of deposition and later transformations of coal-bearing sediments. The studied objects (the Donetsk and Lvov-Volinsk basins — in the USSR, and the Dobrudzha and Svoge basins in Bulgaria) have been chosen because they were well-studied and are stratigraphically comparable.

Location of the basins in the regional structures of South-Eastern Europe

The basins studied are located in zones linking various large structures in the regional tectonic pattern of South-Eastern and Eastern Europe. The largest platforms, e. g. the East-European, West-European, Scythian and Moesian platforms, and the folded regions, e. g. the Carpatho-Balkan Arc (Fig. 1), represent such structures.

The Donetsk basin is located within the vast sublatitudinal Pripyatsk-Dneprovsk aulacogene. Both of them and the eastern extension of the depression (aulacogene),

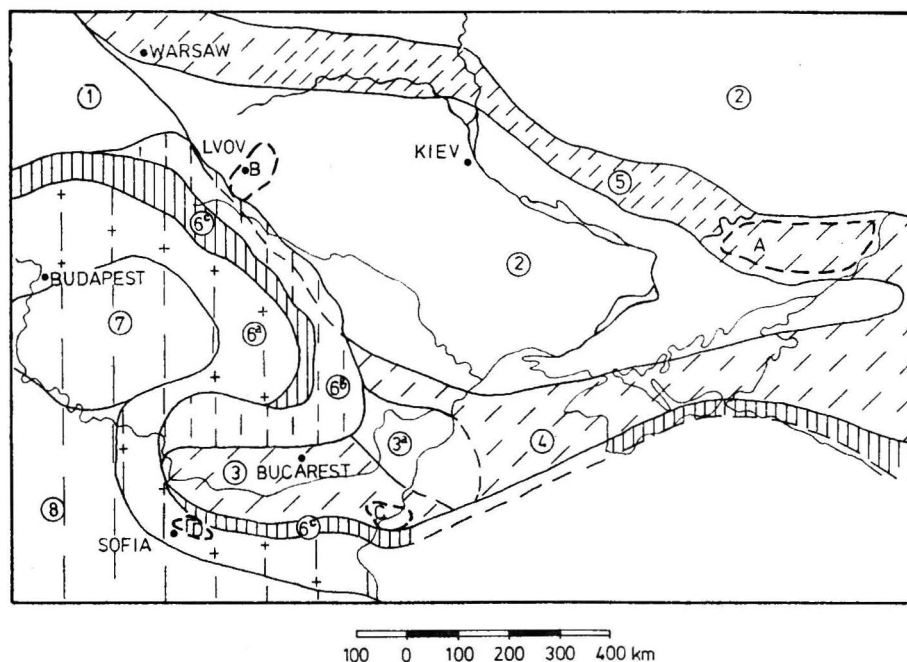


Fig. 1. Scheme of the tectonic zoning of South-Eastern Europe in scale 1:10 000 000
Epi-Caledonian Platforms: 1 — West-European; 2 — East-European.
Early Hercynian structures: 3a — Dobrudzha protuberance; 3 — Moesian platform;
4 — Scythian platform; 5 — Donetsk aulacogene. Alpine structures: 6 — Karpatho-Balkan Arc; 6a — external zone; 6b — Fore-Carpathian fold zone; 6c — internal zone; 7 — Hungarian Depression; 8 — Di-narides.
Coal basins: A. Donetsk; B. Lvov-Volinsk; C. Dobrudzha; D. Svoge

the so-called Karpinski Arch, form part of the Scythian Platform. The Scythian Platform wedges into the East-European Platform from the southeast, extends round in from the south and connects with the Moesian Platform underneath the northern part of the Black Sea (Г а р е ц к и й, 1972).

The Lvov-Volinsk basin lies at the southwestern end of the East-European Platform, inside the Lvov-Lyublinsk depression which, with reference to the Hercynian structural pattern, is situated at the joint linking together the West-European and East-European platform. According to Muratov (М у р а т о в et al., 1972) the depression itself represents a zone of pericratonic dips within the specific tectonic structure stretching from the Sventokshinski Mountain to the Dobrudzha Massif (Z e l i c h o w s k i, 1972).

The coal basins of Bulgaria adhere to the zone linking the Moesian Platform and the southern segment of the Carpatho-Balkan folded belt. The relationship between the platform and its folded framework involves essentially the fault dislocations within the Northern Fore-Balkan fault zone.

The Dobrudzha coal basin is situated on the western slope of the East Moesian Platform's largest North-Bulgarian uplift. The Carboniferous sediments fill an extensive depression which is part of the Vranino horst, the southern most subsided section of Dobrudzha Massif.

The Svoje basin lies in the West-Balkan tectonic zone bordering on the Srednogorie in the South and on the Fore-Balkan in the North. Coal-bearing sediments fill a synclinal structure formed in a Hercynian intermountain trough. The structure is complicated by numerous faults and thrusts of the Ordovician series.

Evolution of sedimentation environments

During the study of Carboniferous complexes in the above-mentioned parts of South-Eastern Europe, the coal basins have been found to adhere to negative morphostructures of various size in the ancient East-European Platform (Lvov-Volinsk basin) and in its Caledonian folded framework (Dobrudzha, Donetsk and Svoje basins). During the Carboniferous this wide territory was subjected to repeated ascending and descending movements causing uneven distribution of washout and sedimentation areas. The most stable region of upward tectonic movements was the Ukraining Shield which remained a washout area throughout the Carboniferous. It supplied most of the material for the Donetsk and Lvov-Volinsk basins. Additional source areas were the Voronezh and North-Volinsk massifs (for the Donetsk basin) and the Sventokshin uplift (for the Lvov-Volinsk basin).

The North-Bulgarian arch and the Caledonian swells further south were the main areas of uplifting within the Moesian Platform. The intermountain Svoje trough, formed in the Variscan mountains during the Sudetian orogeny, had been filled with terrigenous material from the mountain ranges around it.

A common feature of the basins studied is the regressive character of the coal-bearing sequences. However, the tectonic regimes of the separate sedimentation epochs differ considerably.

The beginning of the Carboniferous in the entire region is characterized by predominantly transgressive marine basins dominated by carbonate sedimentation with local manifestations of instability and formation of sandstone conglomerate series interbedded by coal, weathering crusts and numerous surfaces of denudation (Lvov-Volinsk basin).

Upper Visean. During the Late Visean, an extensive regression resulted in accumulation of thick coal-bearing deposits in coastal shallows, large swamped coastal

plains, lagoons and bays. They include the 600 m thick coal series in the Lower Carboniferous coal-bearing formation in the Donetsk basin (Ш у л ь г а, 1981); the Ustilyuzhsk Formation in the Lvov-Volinsk basin consisting of 30 meters of fine-grained bioclastic limestone alternating with black argillites; and the Konare Formation which is the oldest coal-bearing formation of the Dobrudzha basin (Ку л а к с а з о в, Те н ч о в, 1973). The Upper Visean Irechek Formation should also be mentioned here. It consists of oligomictic sandstones up to 600 m thick, deposited probably during a period of slow rise of the Konare Formation coal-bearing sediments to the surface. A packet of quartz sandstones and conglomerates at the top of the Irechek Formation testifies to the continuous influence of chemical reagents on the denuded rocks causing profound changes in their composition.

Namurian. During the Namurian sedimentation began in the Svoге basin, too, forming the Tsarichina Formation and the lower part of the Drenovo Formation. The regressive character of the Namurian sedimentation in the Dobrudzha basin has been definitely established. The coal-bearing sediments of the lower part of the Mogilishte Formation (Те н ч о в, Ку л а к с а з о в, 1972) are characterized by marked polymictic terrigenous rocks and by the appearance of greywacke varieties. The diversity of debris composition, as well as the predomination of rock fragments indicates a sequence of abrupt upward tectonic movements which has determined the deep entrenchment of river valleys, the increased water dynamics and the resulting formation of poorly sorted immature sandstone types.

The Namurian formations of the Lvov-Volinsk basin: Poritsk, Ivanichevsk, Lishnjansk, Buzhansk, Morozovichevsk and Paromovsk have been formed by regressive sedimentation which took place in lagoon-delta and sea environments. The multiple alteration of terrigenous rocks in the sequence with coal layers and with goniatite-bearing limestone interlayers, as well as the well defined rhythm testify to the regularity of oscillations against the background of slow general subsidence. The regressive Namurian sedimentation in the Lvov-Volinsk basin ended with an uplifting and breaks in sedimentation towards the beginning of the Bashkirian stage (Ш у л ь г а, 1960). The quantity of continental deposits in the section gradually increases upwards reflecting the gradual decrease of the rate of sinking.

A characteristic feature of sedimentogenesis in the studied basins is the presence of volcanic products in the Namurian sediments, including tuff, tuffite and tonstein interbeds at the base of the I_1 coal layer Mogilishte Formation; tonstein marking the Namurian C/WestfallianA boundary in the Svoге and Dobrudzha basins, as well as the Namurian B and C boundaries in the upper parts of the Morozovich Formation of the Lvov-Volinsk basin.

During the Late Namurian, the southern marginal parts of the Dneprovsk-Donetsk depression suffered intense upward movements whereas the Central part of the Donetsk basin sank considerably. The process resulted in the deposition of the C_{14} Formation and in sharp reduction peat formation as compared to the same processes in the swamped coastal plain (the C_{13} Formation).

Westfallian. The Lower Bashkirian stage in the Donetsk basin started with advancing transgression and deposition of the Madrikin limestone (C_{21}) and ended with the deposition of the C_{22} Formation. Generally, the stage is characterized by weaker erosion in the source areas, calm sedimentation under coastal-marine conditions and in lagoons where river drift sediments are extremely rare. In the Donetsk basin the formations C_{23} , C_{24} and C_{25} , deposited during the Late Bashkirian, indicate slight subsidence with gradually increasing proportion of alluvial and submarine-delta deposits in the sequence.

Towards the end of the Bashkirian stage, transgression in the Lvov-Volinsk basin resulted in the deposition of the upper parts of the Morozovitch and Paromov Formations. The rate of subsidence gradually decreases and the coastal-marine environment eventually changed to coastal-continental one. The quantity of continental deposits increases towards the top of the section (Krechev Formation).

The Westfallian sedimentation and peat formation on the Bulgarian territory took place under markedly continental conditions. The entire Upper Carboniferous section of the Dobrudzha basin is characterized by a progressive development of an alluvial plain with wandering rivers which have produced numerous intraformational denudation boundaries. The Westfallian Stage of basin evolution was influenced by a general uplifting accompanied by volcanic activity resulting in deposition of whole horizons and portions of formations of pyroclastics (the upper part of the Mogilishte Formation, the lower half of the Macedonian Formation, and some horizons in the Gurkovo Formation in the Dobrudzha basin). At the same time, during the sedimentation of the upper Westfallian C and the lower Westfallian D series, the tectonic regime became stable and extensive swamped lake areas were formed providing favourable environments for accumulation of thick coal-bearing series corresponding to the maximum presence of coal in the Dobrudzha basin.

The regressive stage of development in the Svoqe basin, which had started as early as the beginning of Namurian C, lasted until the middle of Westfallian B. A characteristic feature of that stage is the manifestation of four complete transgressive stages and an incomplete one in the Drenovo Formation. It is these stages of lake sedimentation during which coal formation reached its maximum. After that, the regressive development continued against the background of the advancing differentiation of tectonic movements and expanding coastal-continental and continental environments (the Chibaovci Formation). The dynamism of mountain rivers and streams reflected in the coarse-grained deposits at the bases of the four mesorhythms regularly changes to lake sedimentation in impounded basins towards the top of the rhythms, around which a local but stable peat accumulation has taken place. The process of expanding and stable development of lake sedimentation shows considerably higher rates during the Westfallian D and is clearly manifested in the upper part of the Chibaovci Formation. During the Late Carboniferous sedimentation continued in the Donetsk basin only (Левенштейн, 1975), the so-called Upper Carboniferous coal-bearing subformation, because of the sharp predomination of coastal-continental environments. The tectonic regime is characterized by large amplitudes of oscillating movements and distinct regression. The preserved coastal swamp plain, with a bay and large shallow areas in the north-east, is characterized by a considerably reduced coal formation at the end of the Carboniferous. Intraformational washouts and the gradual expansions of contributed, like subhumid climate in the Dobrudzha basin, to the gradual ceasing of coal formation towards the end of the Westfallian D.

Analysis of the general regularities of paleolandscape evolution

The general regularities of paleolandscape and coal-forming environment evolution during the Carboniferous in South-Eastern Europe have been derived on the basis of the study of the lithological-facies composition of the Carboniferous sediments, the geotectonic position of the basins studied and the regimes of their formation.

In addition to the data obtained during our joint study, the analysis of the basic paleogeographical elements of the studied territory and of the location of areas of coal accumulation in it is also based on materials from the Atlas of paleogeographical maps (Виноградов, Ed., 1961), the Tectonic map of Europe and adjacent areas (edited by Хан, Леонов, 1979), the International map of European coal-bearing deposits (edited by Горский et al., 1967) and a number of other sources (Эремия, 1975; Матеев, 1966; Дачев, 1988; Тенчов, Янев, 1979).

Three major trends in the evolution of the territory (Fig. 2 and 3) have emerged from the constructed paleogeographical schemes and from analysis of sedimentation environments.

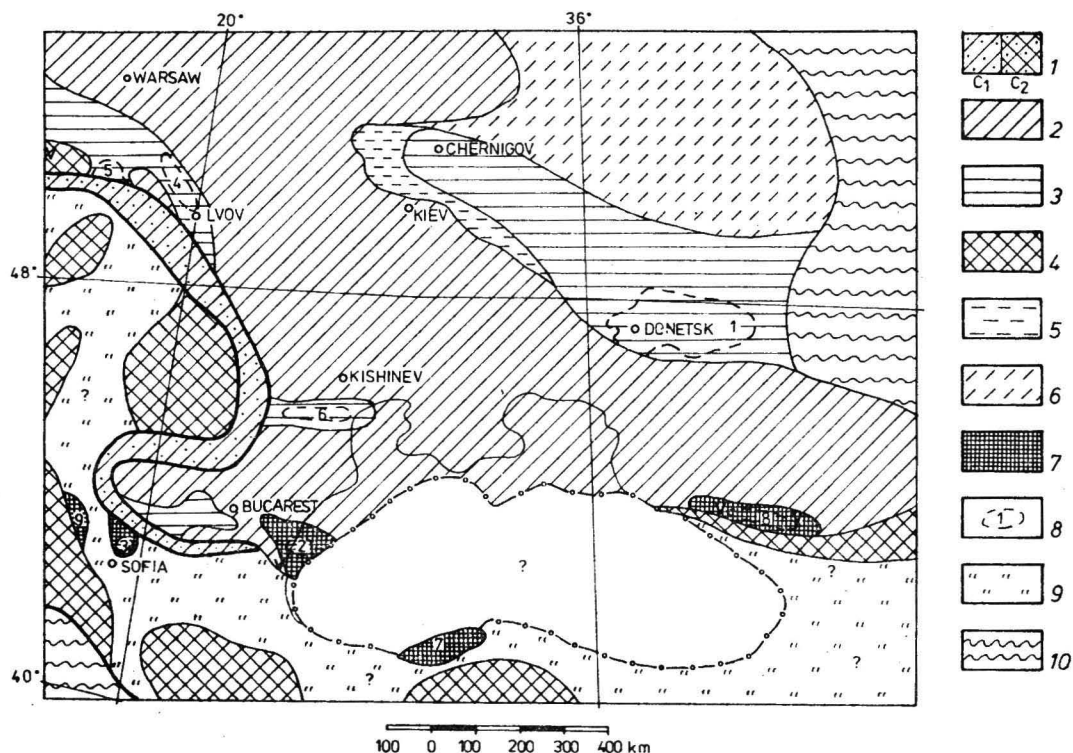


Fig. 2. Scheme of the paleogeographical settings during the Lower Carboniferous.

1 — Carpatho-Balkan arc; 2 — lowland; 3 — shallow sea; 4 — mountain foothills; 5 — swampy plain; 6 — coastal plain; 7 — internal and forebalkan folds; 8 — coal basins and regions; 9 — internal mountain lowland; 10 — sea.

Coal basins: 1. Donbass; 2. Dobrudzha; 3. Svoge; 4. Lvov-Volinsk; 5. Upper Silesian; 6. PreDnestr; 7. Zonguldag; 8. North Caucasian; 9. East Serbian

The first trend consists in the general regressive type of landscape development from pure marine environments during the Early Carboniferous to coastal and intercontinental ones during the Late Carboniferous. The trend reflects the specific time intervals of formation of the studied-coal-bearing deposits, their direct relationship with the orogenic stages of the Hercynian (Variscan) cycle of geotectonic evolution of folded regions. As it is known, the Variscan cycle ended at the end of the Paleozoic with the formation of mountain systems along the south-western, southern and eastern borders of the Russian Platform (Fig. 3).

The second trend consists in the increasingly continental character and better defined characteristics of the individual contemporaneous environments from the east to the west (from the Donetsk to the Lvov-Volinsk, Dobrudzha and Svoge basins). First of all this is reflected in the lithological composition of rocks: increasing grain size of rock constituents, decreasing mineralogical maturity and sorting, increasing variety of clastic components, diminishing content of limestones in the series to their complete absence from the sections of Bulgarian basins. Secondly, the trend is also reflected in the facies of sediments. For example, alluvial fan facies, stream channel facies and facies of fresh-water lake-type inland basins are characteristic of the Svoge and Dobrudzha basins only, whereas the contemporaneous sediments of the Lvov-Volinsk and especially of the Donetsk basin are predominated by coastal facies with

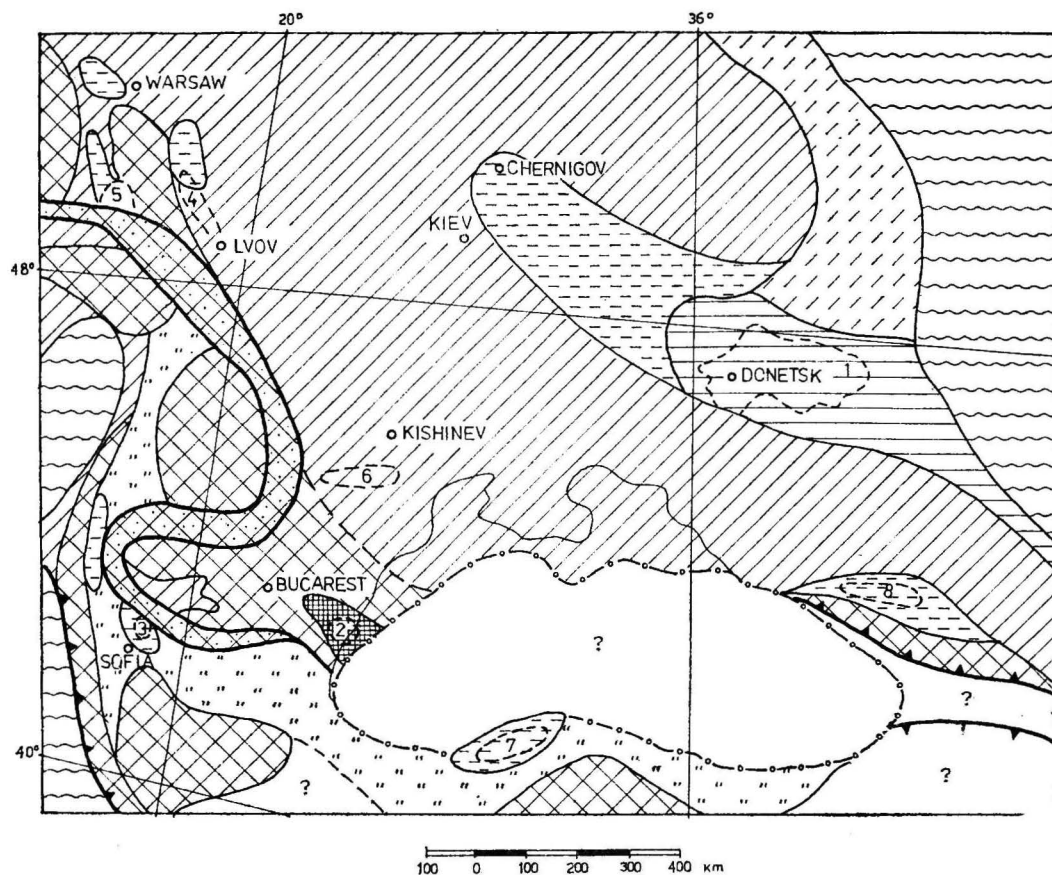


Fig. 3. Scheme of the paleogeographical settings during Upper Carboniferous
The indications are the same as in Fig. 2

extensive lagoon varieties, coastal lakes of normal salinity, bay facies, the series showing a markedly content of alluvial and deltaic varieties.

The above tendency reflects the differences in the positions of coal accumulation areas with reference to the Late Hercynian orogenic zones. The Bulgarian Carboniferous basins were located either inside or at close proximity to mountain structures which has determined their coarse-clastic continental and subcontinental cross-sections with many intraformational discontinuities. At the same time, the largest basins of South-Western USSR were formed in wide plains and around seas with lagoon-bar types of swamped coasts.

The third trend consists of the increasing role of pyroclastics from the north-east to the south-west. The coal-bearing series of Bulgarian basins have been found to contain abundant evidence of volcanic activity including tonstein layers up to 10 m thick at the base of some coal seams (Попова, Матанова, 1981; Попова, 1989); tuffaceous layers and horizons consisting of tuffs, tuffites, and tuff-sandstones. Volcanic rock fragments are also present in the clastic constituent of rocks both in the Dobrudzha and in the Svoge basins. All that means that the pyroclastic material in the Bulgarian Carboniferous sediments is a product of local volcanism the centres of which lies probably in the nearest surroundings of sedimentation basins. Volcanic material has also been found in the Donetsk and Lvov-Volinsk basins (Иванова et al.,

1979), where, however, it is less common forming thin tonstein and tuffaceous layers (Зарицкий, 1970; Черновьянц, 1976; Терещенко, Черновьянц, 1979). It follows therefore, that the material in the South-Western USSR is a product of quite distant volcanism and forms telepyroclastic deposits (Бровков, 1965) with no direct connection to the host geostructural zones. The above trend in the evolution of the basins studied is fully compatible with their position in the Late Paleozoic paleogeographical regions of different seismic and volcanic activity.

Conclusion

As may be seen from the above analysis, all studied coal basins show significant differences in the tectonic regimes and paleogeographical environments of Carboniferous sedimentation inspite of certain similarities in their geological evolution.

The stable character of prolonged subsidence involving oscillation of varying amplitude determined the predomination of sinking to rising stages in Donbass and the maximum speed of sedimentation of 196 m/mln years was reached. The tectonic regime of sedimentation in Dobrudzha and Svoje basins is characterized by a considerably shorter subsidence. According to some authors (Бок, 1989) the space for the Upper Carboniferous sedimentation in Dobrudzha had been already prepared which determined the formation of such thick series consisting of alluvial-deltaic sediments without any traces of brackish-water or marine facies. The rate of sedimentation in Dobrudzha is 54 m per one mln years, and in the Svoje basin it is 48 m.

The lowest rate of sedimentation has been found in the Lvov-Volinsk basin (35 m/mln years). The general subsidence of its floor was interrupted several times by upward movements, especially during the initial stages of sedimentation.

Thus the main differences between the basins studied consist of the rate and duration of subsidence and in the availability of terrigenous material needed for accomplishing a compensated sedimentation.

The formation of thick coal-bearing sedimentary sequences in zones linking ancient platforms with orogenic regions (foredeeps) is a prerequisite for their further purposeful study and for finding zones of non-compensated depressions, so interesting in view of their oil and gas potential.

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