

Geological settings of the metallogenic prognosis in Strandža-Sakar (Southeastern Bulgaria)

Ljubomir Vassileff

Geological Institute, Bulgarian Academy of Sciences, 1113 Sofia

(Received 30. 09. 1993; accepted 23. 11. 1993)

Л. Василев — Геологические обстановки металлогенного прогноза в Странджанско-Сакарском районе (Юго-Восточная Болгария). Странджанско-Сакарский район является частью восточной вулкано-интрузивной области Среднегорской зоны. Он принадлежит к верхнемеловой магматической дуге, которая зародилась и сформировалась на геодинамическом фоне активной окраины Мизийской платформы (Ямболско-Бургасский район) и двух экзотических аккреционных блоков — Странджа-Сакарского и Восточно-Фракийского. Аккреционные блоки — это части коллажной системы, становление которой происходило в верхнеюрское-нижнемеловое время.

Среднегорская магматическая дуга состоит из флишевых трогов и задуговых рифтогенных бассейнов (Черное море). С металлогенической точки зрения ее самая важная характеристика — это верхнемеловой магматизм и его сравнительно хорошо сохранные вулкано-интрузивные аппараты центрального типа. Восточно-Среднегорская вулкано-интрузивная область выделяется наиболее интенсивным, наиболее основным (типично базальтовым с широким диапазоном дифференциации) и наиболее высококалийным магматизмом. Его эволюция и темпорально-латеральная зональность (юг-север) характерна для зрелых островных дуг.

Главное металлогеническое значение имеют разломы следующих групп: субэкваториальной (90—120°), косой (30—40°) и субмеридиональной (170—190°).

В соответствии с их геодинамической обстановкой выделены доаккреционные (экзотические), аккреционные и постааккреционные рудные месторождения. Большинство доаккреционных месторождений относится к стратиформному сингенетическому типу. Вместе с вмещающими их геоконтаксами они испытали дислокационный метаморфизм. Среди них более существенны железо-полиметаллические месторождения. Их прогнозная оценка не дает перспектив.

Аккреционные месторождения немногочисленные и со слабой перспективностью.

Важное значение имеет постааккреционная металлогения. По возрасту выделяются месторождения двух групп: верхнемеловой и позднетретичной. Верхнемеловые месторождения относятся к проксимальному типу и связаны со всеми этапами эволюции вулкано-интрузивных структур. Представлены: антемагматические месторождения (Mg-скарны с магнетитом), интрамагматические (железные $\pm V$ - и Ti-содержащие габбро) и постмагматические (медные — вкрапленного типа $\pm Mo, W$; медно-золото-содержащие полиметаллические жилы и скарны и т. д.). Все эти месторождения хорошо изучены и давно эксплуатируются. Их прогноз сильно ограничен.

Позднетретичные оруденения относятся к дистальному телетермальному типу. Это низкотемпературные сурьмяно-золотые-полиметаллические жилы и цокверки (?). Они слабо изучены и являются перспективными. К перспективным формациям можно причислить и россыпи золота в плио-четвертичных и сеноман-гунонских осадочных породах.

Abstract. Strandža-Sakar covers the eastern part of the Srednogorie zone and is formed like a Late Cretaceous magmatic arc over geodynamic background, represented by the active margin of the Moesian Platform (Yambol-Burgas region) and by two exotic accretion blocks — the Strandža-Sakar

and the East Thracia ones. The latter represent a collage system built in the period of the Late Jurassic — Early Cretaceous.

The Srednogorie magmatic arc includes flysch troughs and back-arc rift basins (the Black Sea). However, the most outstanding phenomenon in metallogenic aspect is the Late Cretaceous magmatism, which have formed relatively well preserved central type volcano-intrusive structures. The Eastern Srednogorie volcano-intrusive area is distinguished for the most intensive, basic (typically basalt with wide differentiation) and highest potassium alkaline magmatism with evolution and spatial-temporary lateral (S-N) zonality characteristic for the mature island arcs.

Subequatorial (90° - 120°), oblique (30° - 40°) and submeridian (170° - 190°) more significant fault systems could be subdivided.

The ore deposits are divided into preaccretion (exotic), accretion and postaccretion depending on the setting. Most of the preaccretion deposits, which have undergone dislocation metamorphism together with the embedding geocomplexes, are stratiforme and syngenetic. The iron-polymetal ore mineralisations with insignificant and low probability prediction assessment are more important.

The accretion deposits are not numerous and are also with low probability prediction assessment.

The postaccretion metallogeny is more important and significant. It includes two age groups: Late Cretaceous and Late Tertiary. The Late Cretaceous deposits are of proximate type, connected with the volcano-intrusive centres of the magmatic arc. The ore mineralisations occur during all stages of centres' evolution: antemagmatic (Mg-scarns with magnetite), intermagmatic (iron-bearing $\pm$ V-, Ti-gabbro) and postmagmatic (porphyry-copper $\pm$ Mo, W, copper-gold-polymetal veins and scarns), etc. The above mentioned ore mineralisations are well studied and at advanced stage of exploitation. The prediction here is strongly limited. The Late Tertiary ore mineralisations have distal, telethermal character and are represented by low temperature antimony-gold-polymetal veins and stockwerkes (?) which are poorly studied and with high perspectives. The gold-bearing alluvial placer, like the recent (Plio-Quaternary), as well as the old (Cenomanian-Turonian) formations could be referred to the perspective ones.

Introduction

Various branches of geological sciences, some related sciences (like geophysics), as well as some universal sciences (mathematics — probability and statistics, etc.) compose the complex, diverse and various scale process of metallogenic prediction. Attempts for independent application of some physico-mathematical methods have been done, proving thus their incorrectness or failing in solving of metallogenic prediction problems. Another quite frequent mistake is being done when defining the perspectives of larger or smaller areas, ore fields or separate deposits, using only metallogenic indicators data (i. e., geophysical and geochemical anomalies) without cogniting and reading the metallogenic factors values or, to be more precise, the values of the metallogenic geological objects — metallotects. Unfortunately, this approach is widely used in practice by most of our research- and mine-producing organisations.

This paper concerns a region in Southeastern Bulgaria, distinguished for high degree of being studied, but still without solved geological and metallogenic problems. The paper studies generally the geological settings of prediction in order to elucidate some new geological approaches of prediction of more important ore and industrial mineral resources in Strandža-Sakar.¹

Geological framework

Strandža-Sakar is considered as the eastern part of the Srednogorie zone (Eastern Srednogorie) with own specific geological and metallogenic features in comparison with the other two parts — the Central and Western ones. The three-part division of the Srednogorie zone has been well grounded by Staniševa-Vassileva (1980) using geodynamics and magmatism during the Late Cretaceous, the most important

¹ This study has been accomplished with the financial support of the Ministry of Sciences and Higher Education, contr. Nr. 617 and NZ-6/91.

period of zone formation. The general geological structure could be referred to in the same respect.

The Srednogorie zone had been built up from the beginning of the Late Cretaceous as a magmatic arc (Boccalletti et al., 1974, 1978; Hsu et al., 1977; Начев, 1978; Начев, 1980; Stanisheva-Vassileva, 1980; Янев & Бахнева, 1980; Василев, 1982 and others) over strongly deformed margin of the Moesian Platform, along which several accretion exotic blocks have been collided during the Early Cretaceous: Serbian-Macedonian, Western Rhodope, Eastern Rhodope, Central Srednogorie, Sakar-Strandža and Eastern Thracian (Василев, 1989; Василев & Стайков, 1991).

Larger part of the accretion collage includes the famous Rhodope massif and its so-called fragments. The difference in the interpretation is that the Rhodope massif is not separated in parts, vice versa, it is integrated by defined exotic blocks of different specific features in compound and structure. Thus, along the edge of the Moesian Platform a tectonic-stratigraphic system has been formed with the participation of different autochthonous and allochthonous elements in compound and unclarified relations.

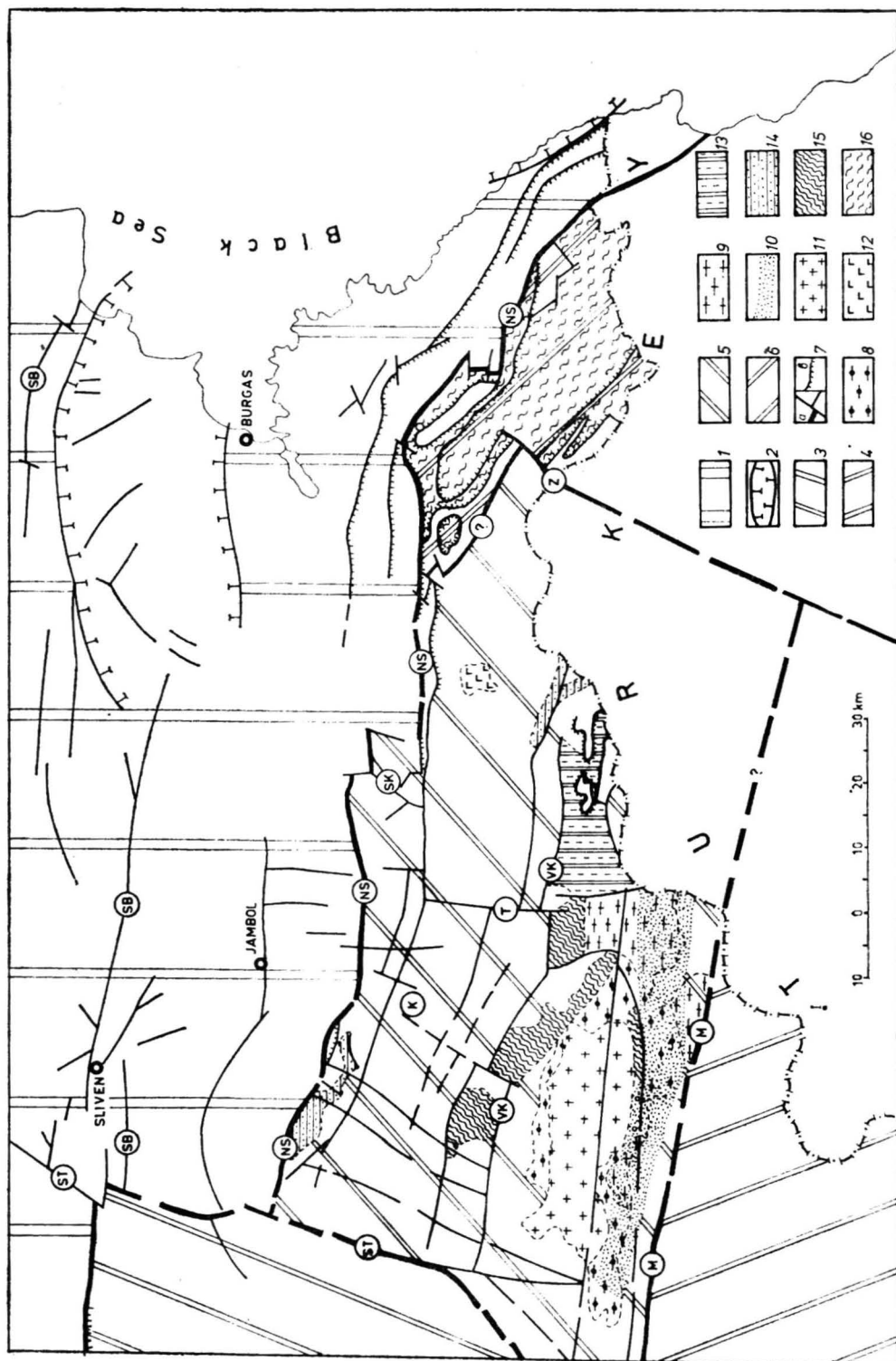
The Srednogorie magmatic arc arises under this conditions during the Late Cretaceous. Later, in Tertiary, it was moved to the north according to the general trend of advanced collision processes in the northern branch of the Alpine orogene. Thus parts of the magmatic arc, and especially the back-arc ones, are overthrust over the platform edge, participating in the building of the famous overthrust-overlap Late Alpine belt, generally identified with the Stara Planina mountain-range (Boccalletti et al., 1974; Бончев, 1940, 1986). This comparatively late process complicates further the structure of the Srednogorie zone and erases quite a lot of her features as magmatic arc, especially in the Central parts. The collision in the Eastern part of the Srednogorie zone is not so strongly expressed and the magmatic arc remains with more preserved elements (i. e., volcanic-intrusive structures). Probably, the Black Sea back-arc rift is responsible for this phenomenon, performing the part of a buffer to the north-vergent Late Cretaceous and mostly Post Cretaceous pressure and collision due to its stretching powers (Stanisheva-Vassileva, 1980).

The three-part division of the Srednogorie zone over the above listed geodynamic background is displayed as follows: a) the Western Srednogorie is formed exclusively over the Moesian Platform; b) the Central Srednogorie — over the homonymous accretion block; c) the Eastern Srednogorie covers parts of two accretion blocks — Strandža-Sakar and East Thracian ones, as well as parts of the active margin of the Moesian Platform; the westernmost end of the Black Sea rift is also established here (Fig. 1).

Morphogeographic, accretion blocks in the Eastern Srednogorie correspond to the Strandža-Sakar region, while the active margin of the Moesian Platform — and the West Black Sea rift to the Yambol-Burgas region. The so outlined regions in Eastern Srednogorie have a structural definition in the Post-Cretaceous plan mostly, besides the morphogeographic one. They are known as Strandža-Sakar anticlinorium and Yambol-Burgas synclinorium respectively, and have their own specific metallogenic character which represents them as definite structural-metallogenic units (regions).

A major feature of the accretion blocks (Strandža-Sakar and Eastern Thracian) is their exotics in relation not only to the Moesian Platform, but between themselves. This is displayed by the features of some geological complexes of the Pre-Late Cretaceous, which have probably arisen at different places. The recent relation of the blocks is considered to have occurred in the Late Jurassic — Early Cretaceous — a period of active tectonic activity (Austrian orogenesis), when the complicated collage system has been built along the edge of the Moesian Platform. Early Cretaceous sediments here have not been established until now, while the Late Cretaceous magmatic arc fossilises the collage and Cimmerian-Austrian structures.

The Strandža-Sakar block is limited from north by the so-called North Strandža fault (Бончев и др., 1969) which could represent the collision zone with the edge of



the Moesian Platform. A part of the southern boundary is considered to pass along the Marica fault. The other part (on Turkish territory) is covered by the young Odrin depression. The southern boundary representing the so-called Zvezdec fault (S a v o v, 1962) divides the Strandža-Sakar block from the neighbouring East Thracian block. To the west the Szazliski-Tvardica fault (N e d j a l k o v, 1983; Б о н ч е в, 1986) have the same role dividing the Strandža-Sakar block from the Central Srednogie block.

The specific geological phenomena of the Strandža-Sakar block are represented by various metamorphic and magmic complexes, as well as by some pre-accretion ore formations. The exotic metacomplexes could be divided in two groups differing by degree of metamorphism (high to medium and low) and protogenesis.

The high- to middle-metamorphic complexes are considered as the relatively oldest — Precambrian (Prerhodopian or Ograzhdenian Supergroup, Precambrian . . . , 1988):

- a) Boturchenska (Sakar) group composed of amphibolites, muscovite to two-mica gneiss-schists and schists, leptinites, graphitic quartzites and metaconglomerates. The last complexes in the Mladinova and Konstantinova formations (Шуляфова & Шиляфов, 1986) represent a specific and to a certain extent an exotic element of the section.
- b) Strazetska (Juruklenska) group composed of porphyroblast gneiss and granitogneiss, leptinites, amphibolites, gneiss-schists, migmatized gneiss.

The specific Lesovo orthometamorphites (Precambrian . . . , 1988; К а м е н о в et al., 1986) pertain to the Strandža-Sakar exotic Precambrian, among which metaaplitites and apliteoid metagranites, normal and porphyroid metagranite, metagranodiorites and metaquartzites are distinguished. The metamorphosed dioritic dykes and sills are concentrated in a strip with almost equatorial spreading between Simeonovgrad and Radovec, along the southern side of the Sakar (К о ж у х а р о в а & К о ж у х а р о в, 1974) pertain to them. The massive of metagabbro (gabbroamphibolites) at the village of Zheljazkovo in Strandža (К а м е н о в, 1976) could also be referred here.

The other group of slight metamorphic, as well as specific complexes, includes the so-called Sakar type of Triassic which exotic nature was explained by Ч а т а л о в (1985_{1,2}). The specific Sakar type of Triassic could be treated as a common complex together with the Late Paleozoic slightly metamorphic sediments found in the Sveti Iliya Highlands and elsewhere in Strandža. This complex as a whole (Triassic&Late

← Fig. 1. Some general structural-geological features of the Eastern Srednogie (Strandža-Sakar) in the background of block-accretion tectonics
1 — Moesian Platform; 2 — Western Black Sea (back-arc) rift. Exotic block-accretion collage system; 3 — Central Srednogie block; 4 — Eastern Rhodope block; 5 — Strandža-Sakar block; 6 — Eastern Thracia block; 7 — fault (a) and thrust (b) faults; the thicker lines display the borders between the exotic accretion blocks; more important ones: SB — Subbalkan fault; NS — North Strandža fault; M — Marica fault; Z — Zvezdec fault; ST — Szazlika and Tvardica faults; SK — Stephan Karadžovo fault; K — Krumovo fault; T — Tundža fault. Exotic geocomplexes in the Strandža-Sakar block: 8 — Boturča (Sakar) group — amphibolites, muscovites to bimica gneiss-schists and schists, leptinites, graphite-bearing quartzites and metaconglomerates (according to Шиляфова & Шиляфов, 1986); 9 — Lesovo orthometamorphites — metaaplitites and apliteoid metagranites, normal and porphyroid metagranites, metagranodiorites and metaquartzites (according to К а м е н о в et. al., 1986); 10 — area of distribution of dykes and sills from metamorphosed dioritic porphyrites (according to К о ж у х а р о в а & К о ж у х а р о в, 1974); 11 — Sakar granite "batholite"; 12 — Zhelyazkovo metagabbro (gabbroamphibolites); 13 — Dervent carbonate phyllitoid schists (Early Paleozoic) (according to Ч а т а л о в, 1988); 14 — Yambol group (Lower Paleozoic — Triassic?) — continental-clastic metasediments (metaconglomerates, metasandstones, metaaleurites with metaquartzporphyritic lavas and tuffs (according to Ч а т а л о в, 1985₁); 15 — Sakar type of Triassic — metaconglomerates, metasandstones, silicate crystalline schists and marbles (according to Ч а т а л о в, 1985₂). Exotic geocomplexes in East Thracia block: 16 — Strandža type of Triassic — metapsamites, metaaleurites, metapellites, phyllitoid mica-carbonate schists, diabase-keratophyre metavolcanites, recrystallised limestones and marbles (according to Ч а т а л о в, 1990)

Paleozoic) includes mostly terrigenous (to coarse clastic) materials with unconstant presence of clayey or carbonate components — metaconglomerates, metasandstones, metasilstones, micarbonate schists, etc. The availability of stronger metamorphosed rocks like mica schists with porphyroblasts of biotite, garnet and staurolite, marbles and amphibolites is observed. Quartz-porphyrines and garnet-porphyrines participate in the section (Н е д я л к о в, 1964; Ч а т а л о в, 1961). These magmatites are different from the Late Paleozoic bimodal magmatism known in the Moesian Platform and its active margin.

Some incompletely defined complexes of the Early Paleozoic (?) are established in the Strandža-Sakar block. Some of them are related with the known diabase-phylitoid formation in the Balkanides, others (like Kavashki metavolcanites, carbonate-phylitoid schists in the area of the Dervent village) remain endemic (local).

Representatives of the so-called "South Bulgarian granites" are comparatively widely distributed in the Strandža-Sakar block. The Sakar batholite, which is considered a specific exotic phenomenon with its Kaledonian age (Л и л о в, 1990), is better studied. This is the most alkaline variety in the group of the South Bulgarian granites in petrochemical aspect, and is the closest to the subalkaline granites and leucogranites with $K > Na$. Another characteristic feature is also the low initial ratio $87Sr / 86Sr = 0.70279$, which is the reason for the mantle origin of the primary magma to be assumed (Л и л о в, 1990). This feature is not typical of granitoides formed in orogenic areas (anatect granites) where the Sakar batholite is "secondarily" found now. This proves once again its exotic nature.

The East Thracia Block to the north and to the east is limited by the North Strandža fault (including the Bosna fault). It is in complicated spacial relations with the Strandža-Sakar block to the west. The Zvezdec fault serves as a partial division here. It passes in the Turkish territory to the south, bordering with the Strandža-Sakar block or covered by the young Odrin depression. The most typical and specific complex in the East Thracian block is the so-called "Strandža type Triassic" (Ч а т а л о в, 1986). Probably a wider age range should be assumed to include a part of the Late Paleozoic (?).

The Strandža type Triassic is allochthonous complex which "co-exists" in complicated relations with small or larger terrains covered by the so-called "Sub-balkanide type Triassic" and Jurassic, which pertain to the south margin of the Moesian Platform and are in autochthonous position (Ч а т а л о в, 1988). The Strandža type of Triassic is characterised by numerous and various in composition rock complexes in the pelagic marine facies mostly, in contrast to the Sakar type of Triassic. These complexes are affected also by relatively weak but general epizonal dislocation metamorphism — they are represented by metapsamites, meta-aleurites, metapelites, phyllites, mica-carbonate schists, metavolcanites, diabase-keratophyres, recrystallised limestones and marbles.

A half of the Bulgarian territory (north) is covered by the Moesian Platform. Its formation and development comprises the whole Phanerozoic. Meanwhile, the Paleozoic geodynamics (structures, sediment settings, magmatism, metallogeny, etc.) are not enough distinct, especially the Early Paleozoic ones, due to either entire cover, or superimposing of later Alpine processes. The introduction of the definition for the Alpine active margin of the Moesian Platform (V a s s i l e f f & V a s s i l e v a, 1981) proved to be useful, and further on it was favourably accepted (B o y a n o v et al., 1989; Д а б о в с к и и др., 1989).

In fact, the Alpine activation of the Moesian Platform margin took place at the end of the Jurassic and at the beginning of the Late Cretaceous. Previously the Moesian margin could be considered as passive with characteristic carbonate-terrigenous shelf facies during the whole Triassic and the Early-Middle Jurassic. The complexes are almost without magmatism with epicontinental sediment ore formations (i. e., iron-bearing Jurassic, Elsas and Lotaringia type).

At the end of or after the passive period (Late Jurassic — Early Cretaceous) traces of activation are observed along the platform's edge, represented by the so-called

Nisch-Trojan (back-arc?) flysch trough (N a c h e v, 1982, 1989). Probably other features of Early Alpine activation within the southern margin of the Moesian Platform also exist, distinguished by metamorphic, magmatic and metallogenic processes, which are not established and described well yet. However, the end of this Early Alpine activation is undeniable, expressed by the following:

1. The South Bulgaria represents an orogenic shore during the Early Cretaceous.
2. Accretion exotic blocks which build the Rhodope integrated massif are collided along the Moesian Platform margin. Their accretion has probably finished at the end of the Jurassic (or Early Cretaceous) with the formation of the so-called "Cimmerian orogene" or "Orogenic collage under collision conditions" (S e n - g ö r, 1985, 1987; C h a t a l o v, 1988). This definition will remain provisionally until sufficient distinct features (including compositional) of orogenic processes during the Late Jurassic and Early Cretaceous are established.

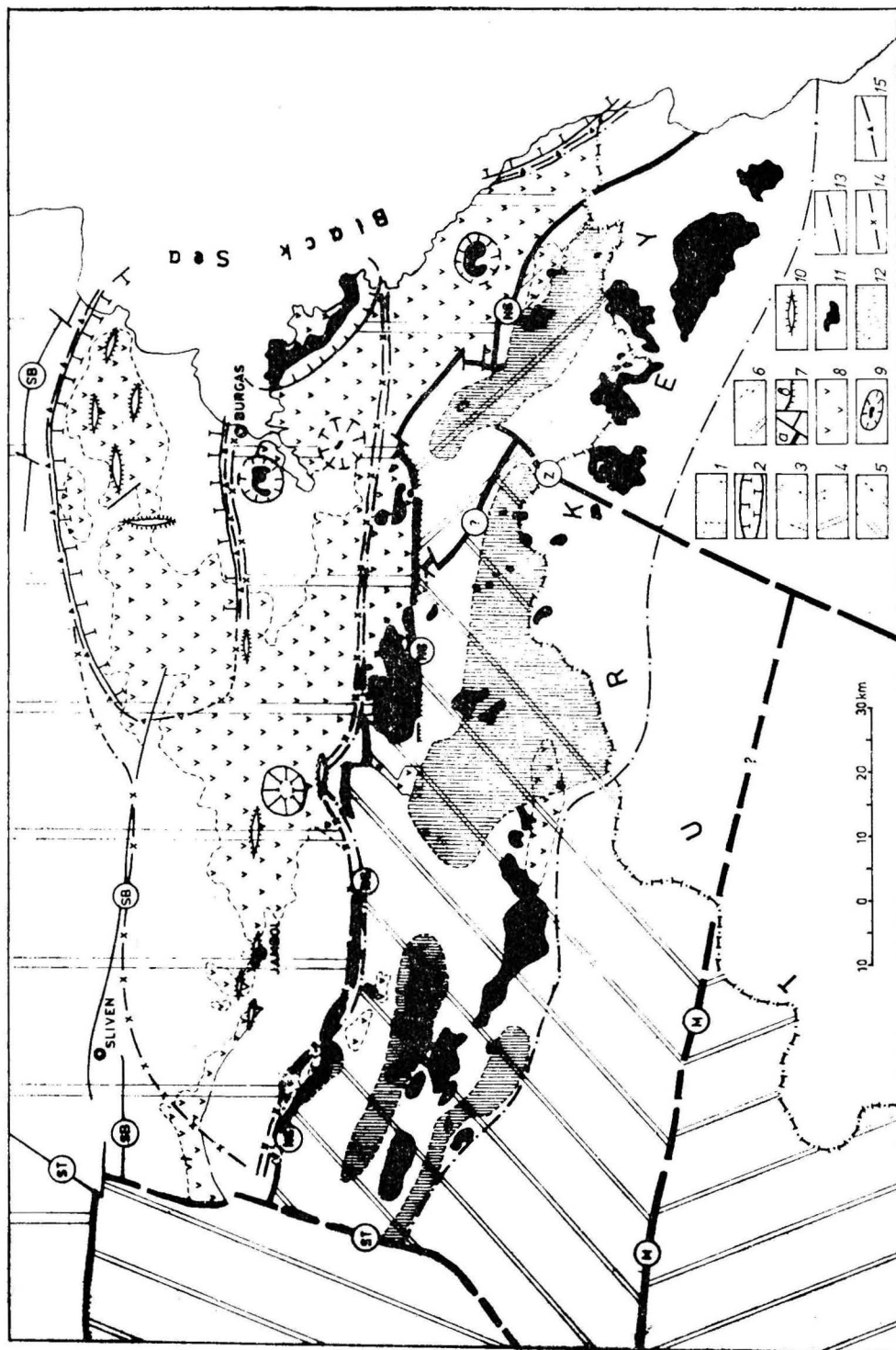
Discovering such features is most successful in the Strandža-Sakar region. The availability here of the Late Jurassic with development of flysch facies is contestable (Ч а т а л о в, 1985_а). However, the increased heat-mass-flow and the dynamothermal metamorphism (Я н и ш е в с к и, 1946, 1947; D i m i t r o v, 1956, 1958, 1959; Ч а т а л о в, 1990) have been beyond doubt for quite long. Different mineral and metallogenic neoformations aged by K-Ar method in the interval of 90-167 Ma, averaging 130 Ma are connected in it.

The Moesian Platform margin, including the collage system activates again at the beginning of the Late Cretaceous, forming a typical and well defined magmatic arc, flysch troughs and back-arc rift basins. The Late Cretaceous Srednogorie magmatic (volcanic-intrusive) arc or the so-called Srednogorie zone in Bulgaria represents only the beginning of a magmatic arc development lasting until end of Miocene, as compared with the rest segments of the Eurasian belt. The Srednogorie magmatic arc is undoubtedly postaccretion (in relation to the "Cimmerian orogene") phenomenon, because its magmatites cut and metamorphose the Pre- and Early Alpine complexes of the accretion blocks. Thus the collage of the latter should have occurred not later than during the Early Cretaceous.

The appearance of the Srednogorie magmatic arc has been caused by subduction processes related with the Tethys or more specifically with the Vardar microocean. The north orientation of the subduction zone is proved by the petrochemical zonality and by the position of the typomorphic porphyry-copper and massive copper-pyritic deposits (V a s s i l e f f & S t a n i s h e v a - V a s s i l e v a, 1988, 1991).

The East Srednogorie volcano-intrusive area (ESVIA) including the Strandža-Sakar is characterised by the thinnest crust (27-30 km) and the most intensive positive gravitation anomalies. The ESVIA occupies extremely to the Black Sea position of the longitudinal petrochemical zonality of the Srednogorie magmatic arc and so it is distinguished for its most intensive, most basic (typically basalt with wide petrochemical evolution) and highest potassium alkaline magmatism (С т а н и ш е в а - В а с и л е в а, 1989).

Four magmatic regions with different petrochemical, facial and regional features of magmatism are subdivided in the East Srednogorie (Fig. 2): Strandža volcano-intrusive region, Yambol-Burgas volcano-intrusive region, North Burgas volcanic region and Luda Kamchia volcanic region (С т а н и ш е в а - В а с и л е в а, 1989). The magmatic evolution is similar to that of the mature island arc with temporal migration from south to north outlying a lateral zonality. The magmatism in the southernmost Strandža region like a frontal arc is poor in potassium. Here are established: early tholeiitic series, slightly differentiated and later Ca-alkaline and high potassium Ca-alkaline series. The magmatism in the next Yambol-Burgas region to the north, which comprises the axes and back part of the volcanic arc, is steadily rich in potassium from the initial to the final stages of its evolution. Here are established: high potassium Ca-alkaline series (in the south edge of the region), shoshonitic and a dominant high po-



tassium subalkaline series with largest evolution. The magmatism in the North Burgas region, accepted as a back-arc rift system, is very rich in potassium. The shoshonitic and subalkaline series are expressed here, dominated, however, by a specific ultra-potassic series, called bulgaritic (Станишева - Василева, 1989).

According to Адамия et al. (1974), the back-arc riftogenesis in the North Burgas region is considered as related with the Adjaro-Trialeti zone in the Small Caucasus and with the formation of the pelagic depression of the Black Sea, being its western end (Боскалети et al., 1978; Станишева - Василева, 1980). Besides the extreme potassic alkaline petrochemistry of the magmatism, there are another proves of the riftogenesis in the North Burgas region:

1. The thinnest earth crust and lack of granite layer.
2. Linear magnetic anomalies, oriented subequatorially in accordance with the Srednogorie zone, turning to southeast before entering the Black Sea basin (Йосифов et al., 1986).
3. Linear character of the volcanic eruptions and widespread pillow lavas (Станишева & Василев, 1966).
4. Thick complex of palagonite tuffs (Станишева - Василева, 1989).
5. Regional hydrothermal metamorphism under low pressure and relatively high temperature (conditions of stretching) with the following facies: (seladonite)-smectite, zeolite, prehnite-pumpellyite, albite-epidote (Станишева - Василева, 1989).

Насhev, 1986; 1989 considers the Srednogorie zone as a complex "trench-island arc" system with characteristic flysch complexes of the Late Cretaceous. The latter accumulate in the two troughs mainly — "The Srednogorie intra-arc trough" and "Emine back-arc trough". Relics from these troughs are best preserved from the influence of later collisional processes exactly in the Eastern parts of the Srednogorie and Stara Planina.

Tephroidic or tephroturbiditic ingradients, which are almost absent in the Emine flysch, are widely spread in the Srednogorie flysch, due to the spacial interrelation of the submarine volcanic activity and flysch formation in the Srednogorie "intra-arc trough". However, the characteristics, position and evolution of the so-called "Balkan arc" remains unclear (Насhev, 1986).

The Balkan (Stara Planina) overthrust-overlap zone is located to the north of the Srednogorie zone (Бончев, 1986; Бончев, 1978). As far as the Srednogorie magmatic arc is concerned, the Stara Planina area is considered as a back-arc thrust belt (Боскалети et al., 1974) since the Late Cretaceous and further (Ilirides).

The Balkan overthrust-overlap zone is formed under conditions of advanced collision and compression, which captivated parts of the Srednogorie magmatic arc (Central Srednogorie). The process is the weakest in the East Srednogorie due to the buffer influence of the back-arc riftogenesis.

Fig. 2. Geological setting, facies and petrochemical zonality of the Late Cretaceous magmatic complexes — the major metallogenic factor in the Eastern Srednogorie (Strandža-Sakar) (according to Станишева - Василева, 1989; Дабовски et al., 1989) 1—7, the same as on Fig. 1; 8 — general area of Late Cretaceous volcanogenic-sediment complexes outcrop; 9 — central polygenic volcanoes with domination of basic and intermediate (rare acidic) magmatic complexes; 10 — linear volcanoes, again with domination of . . . ; 11 — Late Cretaceous multiphase intrusions, differentiated with basic to acidic character; 12 — areas of distribution of compound Late Cretaceous dyke swarms ("sheeted" type) with basic to intermediate character. Petrochemical areas of: 13 — Ca-alkaline (CA) magmatism with tholeiitic character in the initial differentiates (TH) and high potassium Ca-alkaline character (HKCA) of the more acidic differentiates; 14 — high K-subalkaline (HKTR) magmatism at places with shoshonitic (SH) character; 15 — hyper-K-alkaline (bulgaritic, BG) magmatism

The Strandža-Sakar area studied remains to the south, beyond the Stara Planina overthrust-overlap zone. For that reason we will not discuss the latter here, nevertheless the numerous and interesting metallogenic problems offered.

The Tertiary collisional processes are followed by the formation of many larger or smaller collapse structures in South Bulgaria (graben-like or normal depressions). In South Bulgaria they are covered mostly with two age-defined complexes:

1. Paleogene (Eocene-Oligocene) — continental, molasse at places and marine coal-bearing sediments (breccia-conglomerate-sandstone and calcareous-marly).
2. Neogene — continental, at places coal-bearing sediments (conglomerate, sandstones and clays).

From the fault systems in Southeastern Bulgaria, we intend to discuss only the dominant ones, represented during the Alpine orogeny (Fig. 1). Older — Hercinian or Caledonian fault systems are possible to exist, but their fixing in the recent imposed structural plan is rather difficult and more or less imaginary. There are difficulties in decoding the Alpine fault deformations, especially their differentiation in time. In all cases the earlier formed faults, tearfaults, flexures, overlaps, overthrusts, etc. have been post and probably repeatedly activated.

The fault systems in South Eastern Bulgaria could be divided in the following groups (according to Бончев, 1986):

1. Subparallel or subequatorial (90° - 120°), including the following directions: Balkan (about 90°), Marica (about 100°) and Berkovica (about 120°).
2. Oblique (30 - 40°), including the Tvardica direction.
3. Submeridian (170 - 190°), including the following directions: submeridian (about 190°) and Struma (about 170°).

The subparallel fault systems are represented by the following more important (the names are not generally adopted): Subbalkan fault, North Strandža fault (including the Bosna fault), Voden-Kamenoreč fault, Marica fault.

The Subbalkan fault conditionally marks the north boundary of the East Srednogorie, as far as the development of the magmatic arc to the north interrupts or remains undeveloped passing in the area of the back-arc thrust belt.

The North Strandža fault marks the zone of collision of the accretion blocks (Strandža-Sakar and East Thracia) with the active margin of the Moesian Platform (Басилев, 1989). This boundary is relatively "calm" in the western parts of the Strandža-Sakar area, in the region of the Sveti Iliya Highlands, and provides an "illusion" of normal distribution of the magmatic arc Late Cretaceous materials over Early Mesozoic and Late Paleozoic metacomplexes in the Strandža-Sakar block. The North Strandža fault in the eastern parts of the Srednogorie is strongly broken up and has a complex character, covering other neighbouring parallel faults at a distance of 100 km. (Strandža frontal strip, Чаталов, 1973). Relatively weak horizontal movements occur — abrupt northvergent overlap (*Tectonic structure* . . . , 1971). The main movements are vertical especially during the Late Cretaceous and afterwards, when the troughs in the magmatic arcs are being formed and filled up. The strip of intensive faulting, vertical movement and collapse of giant blocks (Grudovo group) are formed then parallelly to the fault (Антончев et al., 1977).

The Voden-Kamenoreč fault (Бончев et al., 1969) marks the south boundary of distribution of the Late Cretaceous intrusive magmatism in the Strandža-Sakar area, contributing to the formation of peculiar Voden graben, filled with Late Cretaceous magmatites in volcanic and subvolcanic facies.

Several faults with Berkovica direction are found to the west of Tundža river between the two pointed out large subequatorial faults (Недялков, 1988; Строев et al., 1986; Савов, 1983). This area corresponds to the Yambol-Elhovo depression and many of the faults are established due to the displacement and alterations of the Pre-Neogene underlying geocomplexes. The following faults: North Sveti Iliya, Gra-

phitovo, South Sveti Iliya, Belibreg, Gledačevo, Balgaren, Knjazevo-General Toshevo, etc., were established.

С а в о в (1983) points out two more subparallel faults with Berkovica direction to the south of the Voden-Kamenoreč fault — the Ustrem and North Sakar ones.

The Marica fault is not popular within the Strandža-Sakar area. It probably passes along the Harmanli-Svilengrad in Bulgaria, north. It is assumed as delimiting structure between the East Rhodope and Strandža-Sakar block, i. e., like a southern boundary of its specific geocomplexes (for example, the Lesovo orthometamorphites).

The oblique faults with Tvardica direction are quite distributed in the Strandža-Sakar area, though they do not have the dimensions and the standards of the subequatorial fault system. Some more important systems of oblique faults known as Zvezdec fault, Stephan Karadžovo fault, Krumovo, Chukarovo, Sazlijski, Tvardica and others oblique faults could be mentioned.

The Zvezdec fault (Zvezdec dislocation, С а в о в, 1961) is considered as a crypt and deep rupture (Odrin-Bosna, Б о н ч е в et al., 1969). Horizontal shifts up to 5 km to the northeast, together with small collapses, occur on its surface. The Zvezdec fault is very important as a separating structure ("tectonic touch plane / surface", Б о н ч е в, 1986) between the two different accretion blocks — the Strandža-Sakar and the East Thracia).

Such distinctive role have *the Sazlijski and Tvardica faults* which separate the Strandža-Sakar from the Central Srednogorie block. The Sazlijski fault (Н е д я л - к о в, 1983, 1988) represents also the left tear fault system with shifting of several tenths km, opposing two rock complexes different in composition and age from both sides of the structure. To the east of the fault within the "cut" Central Strandža anticline and integrated Sveti Iliya monocline, a complete range of stronger and weaker metamorphosed and nonmetamorphosed rock complexes from the Pre-Cambrian to the Late Cretaceous occurs. To the west of the fault, from Nova Zagora to Tihomirovo, only one enigmatic complex of graphite-bearing phyllite schists alternated by thin interbeds of sandy limestones, sugar-like coarse crystalline marbles and tectonic breccia is established. The paleorelief displacement from the fault's both sides reaches 300 m. Olistostromes, rotation and intrusion of small intrusive Late Cretaceous bodies occur within the fault and its parallel satellites (comparatively 10 km). The Sazlijski fault to the north of Nova Zagora is partially fossilized by andesite-basaltic magmatism marking the major movements over it before the Late Cretaceous. The above mentioned data confirm the appearance of the structure under the conditions of Middle Mesozoic accretion collage of neighbouring accretion blocks — the Strandža-Sakar and the Central Srednogorie ones.

The Stephan Karadža fault (S а в о в, 1985) cuts obliquely the western pericline of the Bogdanovo-Stoilovo antiform together with the right directed movement and pushing to the north. It is assumed that this oblique fault together with the subequatorial extension of the Bosna dislocation here have been consolidated from "postkinematic, polyphases, Late Cretaceous Oman pluton".

Several oblique faults with Tvardica direction are established by surface outcrops or boreholes to the west of Tundža, between the Sveti Iliya Highlands and Sakar Planina: Krumovo (Krumovo fault belt, П а н а й о т о в, 1968), Chukarovo (С т о е в et al., 1989), Topolovgrad, etc.

The Krumovo fault passes along the line connecting the villages of Goliam Manastir and Krumovo. The right side is moved to the northeast with about 4 km. This is established by the terrain's morphology and by the deformation of earlier positive fault structures and their parallel grabens with subequatorial direction.

The most important representative of the submeridian faults we would like to outline is *the Tundža fault* (С а в о в, 1983) which includes the following separate structures: Lesovo fault, Malkosharkovo, Mandrensk, Konevec and Yambol faults. The general direction is 5-10° with penetration depth of 20-25 km; it is averagely 5-6

km wide. The Tundža fault is primarily and directly related with the formation of the Elhovo depression filled with Late Neogene coal-bearing molasse. However, it is supposed that the fault structure originates from the Late Cretaceous and has been activated during Eocene and at the end of Miocene-Pliocene (С т о е в et al., 1986).

Metallogeny and prognosis

The ore (including some of the non-ore) mineral resources in Strandža-Sakar, detached like ore formations (ore and ore-bearing formations; В а с и л е в, 1981_{1,2}) are represented in Table 1. (1-A, 1-B, 1-C).

The deposits' distribution and the ore manifestations in three different metallogenic settings, like preaccretion (exotic), accretion (actually accretion) and postaccretion (В а с и л е в, 1990; В а с и л е в & С т а н е в, 1991) are quite peculiar and new features of the formation analysis. The selection of the alpine accretion as one of the major patterns of metallogenic settings in Strandža-Sakar was driven by the following circumstances:

1. Indicators of tectonic events related with the margin of the Moesian Platform and occurring mostly during the Mesozoic and the Neozoic dominate in the Eastern Srednogie (Strandža-Sakar respectively). Autochthonic geological complexes which (like in the Central and Western Balkan) testify for some more defined geological settings and geodynamic processes of the Middle- to Late Paleozoic (Hercinides) are absent or weakly represented here. In other words, to the east of the Tvardica fault shief there are not or, more precisely, are not established Hercinidian elements, which are observed in the Central and Western Balkan, and in the margin of the Moesian Platform. Besides, the geocomplexes of the Strandža-Sakar assumed as Paleozoic, display exotic character and alochthonous position (?), and could not be correlated with those from the Central and Western Balkan.
2. The Tethys ocean during the Early Mesozoic open with spreading and forming of a specific crust (Triassic). The Moesian Platform (including the margin) undergoes passive development with partial and local fast undeveloped epicontinental riftogenesis with bimodal basalt-rhyolitic magmatism (Я н е в, 1987; Б о н ч е в, 1986; М о н о в et al., 1971). Local ensimatic arcs with trench and deep sea sediments, diabase-keratophyre magmatism and iron-polymetallic ore formations, Bessy type, occur in some places beyond the boundaries of our country. These complexes bear features of dynamothermal metamorphism with green-schist facies.

← Fig. 3. Metallogenic scheme of Pre-accretion (up to Early Cretaceous) and Post-accretion (Late Cretaceous — Tertiary) ore mineralisations in the Eastern Srednogie (Strandža-Sakar) (compare with Table 1)

1—7 — the same as on Fig. 1; Morphology: 8 — impregnated: a — deposits and ore mineralisations, b — ore fields of the iron-titanium-bearing gabbro and limited copper mineralisations in the Rossen ore field; 9 — layered and layer-like (stratiforme, stratified) of ore-bearing sandstones and mica-carbonate schists, manganese-bearing phyllites and calcoschists, polymetal-iron-bearing phyllitoid and mica-calcoschist diabase-keratophyre formation, ore-bearing epicontinental formation range, manganese-ore-bearing tuff-carbonate formation; 10 — irregular bodies: (a and b, like 8) of magnetite manganese and calcium scars, sheelite-bearing calcium scars, copper-polymetal apocarn ore formations, antimonite-gold-polymetal ore formations, etc.; 11 — stockworks: (a and b, like 8) of the porphyry-copper formation ($\pm$ Mo, W); 12 — veins (a and b, like 8) of the quartz, quartz-wolframitic, copper-gold-polymetal and fluorite-barite-polymetal formation. Genetic type: 13 — orthomagmatic (magmatic); 14 — pneumatholitic; 15 — hydrothermal; 16 — volcanogenic (hydrothermal)-sediment; 17 — sediment; 18 — metamorphic; Composition: 19 — oxides; 20 — native elements; 21 — sulphides, sulphuric salts; 22 — preaccretion (a) and accretion (b) deposits (before the Late Cretaceous); 23 — postaccretion deposits (Late Cretaceous and after the Late Cretaceous); 24 — Late Cretaceous intrusions: a — basic and intermediate to acidic, b — acidic

Table 1

Metallogenic settings and ore formations in Strandža-Sakar (Eastern Srednogorie)

Table 1-A

Precambrian settings (up to Early Cretaceous)				
Strandža-Sakar Block		East Thracia Block		Moesian Platform
Ore-bearing formations	Ore formations	Ore-bearing formation	Ore formations	Ore-bearing formations
Litho-: Iron-bearing sandstones and mica-carbonate schists (magnetite, hematite, $\pm$ psilomelane); Topolovgrad, Krepost (metamorphosed)		litho-: polymetal-iron-bearing phyllitoid and mica-calcoschist diabase-keratophyre formation (pyrite, sphalerite, halcopyrite, galenite, hematite); Gramatikovo ore field (metamorphosed)		litho-: iron-bearing epiconitine-nak-Zvezdec-Brashian (weakly metamorphosed) — lower iron-bearing marly-calcareous formation (hematite, hydrogoethite, Fe-chlorites)
Manganese-bearing phyllites and calcoschists (psilomelane); Goliam Dervent (metamorphosed)		iron-titanium-bearing phyllitoid diabase-keratophyre formation (Fe-chlorite, ilmenite); Stoilovo (metamorphosed)		— middle iron-bearing argillaceous-silty formation (Fe-chlorites, siderite)
Meta-: Magnetite metabasites; Topolovgrad				— upper iron-bearing sandy-calcareous formation (hematite, hydrogoethite, Fe-chlorites, siderite)
Marbles; Topolovgrad, Malko Tarnovo, etc.				

Table 1-B

Accretion settings (Early Cretaceous)			
Strandža-Sakar Block		East Thracia Block	
Ore-bearing formations	Ore formation	Ore-bearing formations	Ore formations
fluorite-barite-polymetal formation (quartz, fluorite, barite, pyrite, sphalerite, halcopyrite, galenite); Ustrem ore field		meta-: magnetite-hematite Ca-scarns; Zubernovo	lead-zinc (?); Surcevo

Table 1-C

Postaccretion settings (Late Cretaceous and Tertiary-Quaternary)				
Magmatic Arc				
Frontal Arc Strandža-Sakar region		Own volcanic arc Yambol-Burgas region		Back-arc rift North Burgas region
Ore-bearing formations	Ore formations	Ore-bearing formations	Ore formations	Ore-bearing formations Ore formations
Magma-: Iron-titanium-bearing gabbro (ilmenite, titanium-magnetite); Velikovec	porphyry-copper formation (pyrite halconite, -molybdenite, -scheelite); Prohorovo, Malko Tarnovo	litho-: manganese-iron-bearing tuff-carbonate formation (pyrolusite, psylomelane, hematite); Yambol, Grudovo	copper-gold-polymetal vein formation (specularite, pyrite, molybdenite, halconite, sphalerite, galenite, gold, busmuthinite); Rosen, Zidarovo, Bakadjik, etc.	
Gabbro-diorites (for mineral wool); Krumovo	copper-gold-polymetal apocarn formation (specularite, pyrite, molybdenite, halconite, bornite, sphalerite, galena, gold, busmuthinite); Malko Tarnovo	titanium-magnetite shoreline sandstones; Burgas	copper-zeolite formation (?); Burgas	
Meta-: Magnetite magnesium scarns ($\pm$ ludwigite); Krumovo, Drianovo		gold-bearing alluvial placers; Novoselec, Fakija, Zidarovo		
Magnetite calcium scarns; Malko Tarnovo	quartz-wolframite formation; Polski Gradec	magma-: basalts, basanites, etc. (for petrurgy and decoration); Micurin, Yambol		
Scheelite-bearing calcium scarns; Malko Tarnovo, Polski Gradec	antimony-gold-polymetal formation (pyrite tetrahedrite, tennantite, gold-silver tellurides, antimonite, galenite, sphalerite, halconite); Dobroselec			
Litho-: Zircon-bearing alluvial placers; Kosti				
Gold-bearing lacustrine-alluvial placers; Slivarovo				

Their elements are established in allochthonous position in the East Thracia block (Strandža type Triassic, Gramatikovo).

Weak attempt of activation of the Moesian Platform margin occurs during the Late Jurassic with the formation of the "fast calmed down" Nish-Troyan trough (Nachev, 1989).

3. The intensive geodynamics along the edge of the Moesian Platform begins during the Early Cretaceous when the collage system of exotic accreted blocks is formed. After this process, which is only the beginning of very significant geodynamic reconstructions, the activity of the margin increases together with the building of the magmatic arc with back-arc riftogenesis and thrust belt during the Late Cretaceous and the Tertiary, ending with a collision Alpine orogene, which is best represented in the Central Srednogie.

The preaccretion metallogeny (Fig. 3) is characterised by specific deposits and ore manifestations of exotic character observed in the accretion blocks (Strandža-Sakar and East Thracia). In other words, the preaccretion deposits and ore manifestations are one of the elements of the accretion blocks. The Early Mesozoic sediment ore formations from the Moesian Platform cover, which are related with its passive period (Permian-Triassic, Early-Middle Jurassic), also pertain to the preaccretion metallogeny.

A general feature of the preaccretion metal formations, like their constructing geo-complexes in Strandža-Sakar, is their dynamothermal (dislocational) metamorphism in epizonal facies (alpine type) predominantly.

Most of the preaccretion ore formations pertain to the ore-bearing geological formations, litho- or metaformations (Table 1-A, Fig. 3). The latter represent the major metalotects, because they compose stratiform, syngenetic mineralisations. Due to the allochthonous character of the preaccretion mineralisations located in different accretion blocks and in the activated Moesian Platform margin, it is difficult to outline a metallogenic zonality, which reflects on the possibilities to draw some regularities of mineralization distribution. The preaccretion deposits and ore manifestations are with relatively limited dimensions and low concentrations of useful components. Most of them, have no industrial importance, except the Gramatikovo ore field, which is almost exhausted. Due to the allochthonous and secondary dislocation-metamorphic processes followed also by dispersing of useful components, the prediction assessment is very difficult and with low degree of probability.

The accretion deposits and ore manifestations are not numerous (Table 1-B, Fig. 3). The most important one is the Ustrem ore field and is under exhaustion. The deposits have characteristic position in the bordering zones between the accretion blocks, as well as in the blocks themselves, depending on their permeability and paleohydrodynamics. The deposits are rather specific and have always been considered as enigmatic in genetic aspect. Without relation with definite magmatism they are hydrothermal, formed in wider interval (epi- to meso-). The mineralisation in the Ustrem ore field has been aged by the K - Ar to 140 Ma (Скендеров et al., 1986). This period coincides (Лилов, 1986; Пальшин et al., 1989) with the most intensive regional Alpine dynamothermal metamorphism in Southeastern Bulgaria, characterized by intensive endogenic heat-mass-flood, amagmatic probably. The prediction assessment is with low degree of probability as well, like of the preaccretion deposits for the same reasons — unfavourable influence of post deformation processes. This fact was proved by detail studies carried out in the three objects pointed out in Table 1.

The postaccretion metallogeny in Strandža-Sakar is more variable (Table 1-C, Fig. 3). It comprises a number of deposits of importance to the resource potential of Bulgaria. The deposits could be divided in two age groups: Late Cretaceous and Late Tertiary (Neogene-Quaternary).

The Late Cretaceous deposits are connected with volcano-intrusive structures of central type of the magmatic arc, which represent the major metalotect (Василев & Станишева - Василева, 1972; Vassileff & Stanisheva - Vas-

sileva, 1981; Василев, 1982). The mineralisations occur in all stages of magmatic centres evolution, and more precisely:

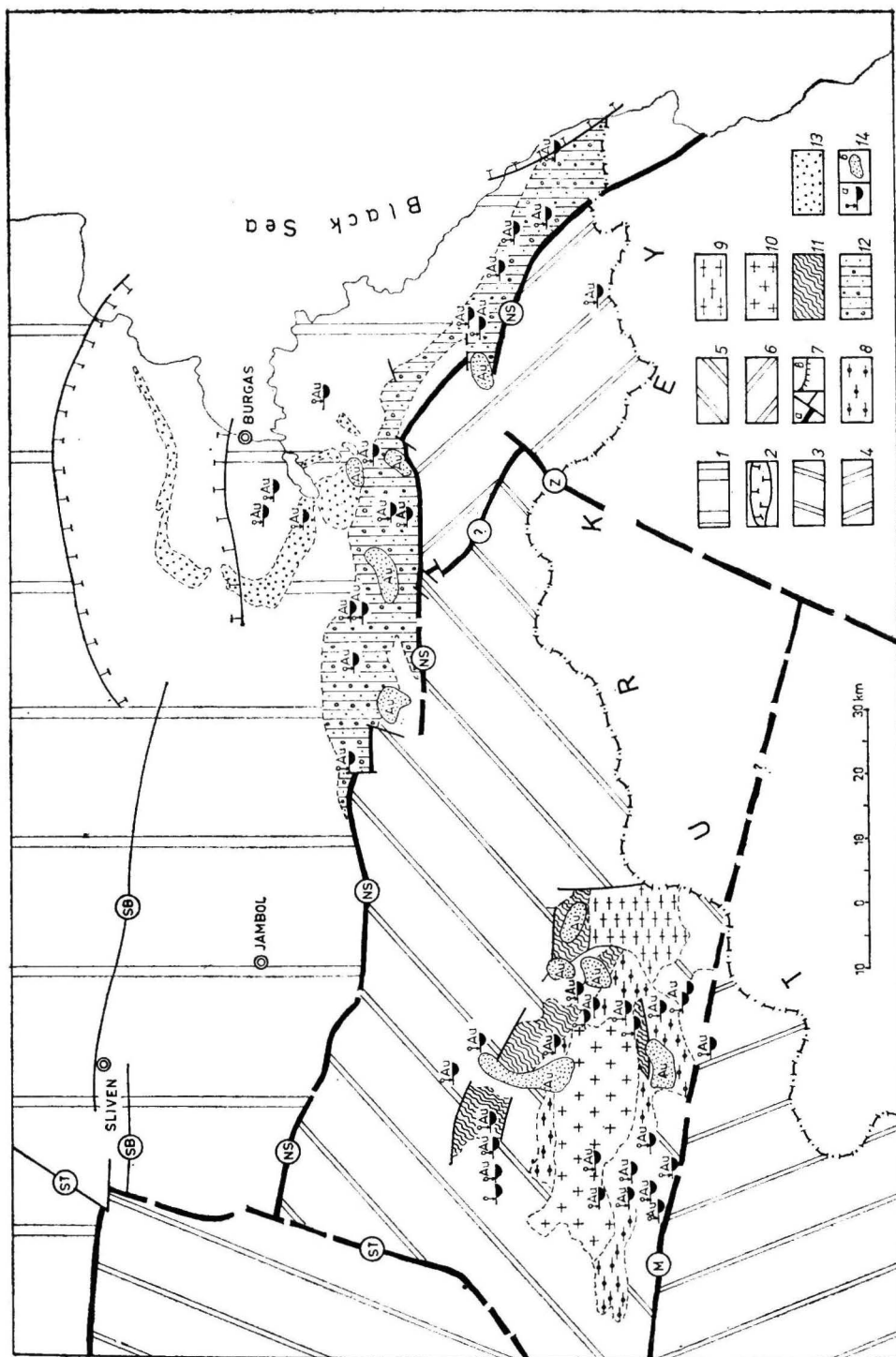
1. Antemagmatic stage of rise of differentiated and nondifferentiated magma until its final location in the earth crust. A front of advancing fluids is formed ahead of the arising magma, causing progressive metamorphism which under the conditions of carbonate environment leads to the formation of magnesium scarns with magnetite (Krumovo) (Василев, 1979; Vassileff, 1971).
2. Magmatic (intermagmatic) stage during which the magma, finally located in the crust, crystallises. The mineralisations are represented by vanadian bearing titanium-magnetite and ilmenite which occur in two "moments" of crystallisation of gabbro rocks — early stage before the major rock formation pyroxene and plagioclase (accessory type) and late one — after the mentioned non-ore minerals (sideronite type) (Krumovo, Velikovec) (Димитров & Каменов, 1941; Василев & Станишева, 1963).
3. Postmagmatic stage during which a complete range of proximate deposits with relatively high temperature occur: porphyry-copper ($\pm$ Mo, W) — (Prohorovo Malko Tarnovo), quartz-tungsten (Polski Gradec) and copper-gold-polymetal vein and aposcarn (Rosen, Varli Briag, Zidarovo, Bakadjik, Malko Tarnovo). Some distal hydrothermal-sediment manganese ore manifestations (Grudovo, Yambol) could be mentioned here, as well as insignificant amount of copper-zeolitic high temperature mineralisations.

The magmatism represented by linear magmatic structures within the West Black Sea rift is with unestablished metallogenic importance yet.

As the Late Cretaceous magmatic centres are the major metalotect, then some metallogenic zonality could be outlined only as subordinate to the lateral petrochemical zonality of the Late Cretaceous magmatism in the Eastern Srednogorie (Станишева - Василева, 1986; 1989). Thus two metallogenic zones could be drawn only for the Late Cretaceous mineralisations, which coincide with the Strandža-Sakar and Yambol-Burgas regions (Василев, 1982). In the first region which is the frontal part of the magmatic arc, the magmatism is relatively poor in potassium, and mostly three magmatic series are distributed here — early tholeiitic, slightly differentiated and later Ca-alkaline and high-potassium Ca-alkaline. The metal mineralisations are the most characteristic, related with gabbro and scarns, as well as with porphyry-copper deposits, associated with aposcarn copper mineralisations. In the second region, representing a volcanic arc, the magmatism is permanently rich in potassium and is represented by the following series: high potassium Ca-alkaline, shoshonitic and high potassium subalkaline ones. The copper-lead-gold-polymetal vein formation is the most characteristic one, partially occurring in aposcarn type and in some deposits of the Strandža-Sakar region.

The postmagmatic hydrothermal formations are considered as most perspective from the mentioned types of formations related with the Late Cretaceous magmatism, but only within the limits of the already known and not well studied yet volcano-intrusive centres — Zidarovo, Bakadjik, Iglika, Oman-Fakija, etc. Other ore-bearing volcano-intrusive centres found on the surface or at reachable depth with industrial mineralisations cannot be predicted reliably.

The Late Tertiary hydrothermal antimony-gold-polymetal formation established recently around Dobroselec (Стоев et al., 1986, 1989; Бахнева et al., 1988) is probably distantly formed with the participation of favourable fault system, the major metalotect. Attention should be paid to the cross-points of subequatorial and submeridian faults, which more important representatives have already been mentioned above. For the time being, the area of the Monastery Highlands is considered the most perspective, though it could be expanded obviously within the whole East Marica and Elhovo depression where favourable fault systems for ore mineralisations have been established.



The Plio-Quaternary placers which include various useful minerals: titanium-magnetite (coastline sands around Burgas and Pomorie), zircon and sheelite (the river Veleka at the villages of Gramatikovo and Kostin) and gold (along the south boundary of the Burgas-Yambol region and in Sakar, Fig. 4), deserve special attention in the metallogeny of Strandža-Sakar (East Srednogorie). The gold has been known and yielded until complete exhaustion from ancient times. Prediction of secondary gold deposits could be done in two aspects: a) in respect of numerous regions from the river network which small capabilities are under study; b) in respect of some "intermediate collectors", like the coarse terrigenous sediments of the Late Cretaceous (Grudovo group) and Late Eocene in the Yambol-Burgas region (Fig. 4). Similar positive prediction assessment could be done for the terrigenous metasediments of the Sakar type Triassic (Fig. 4). The second aspect, totally unknown, deserves attention.

References

- Antonov, M., Bairactarov, I., Petrova, A., Popov, P., Naftali, L. 1977. Upper Cretaceous resedimentation phenomena in the North-Eastern Strandja, SE Bulgaria. — *C. R. Acad. bulg. Sci.*, 30, 10; 1451-1454.
- Boccalletti, M., Manetti, P., Peccerillo, A. 1974. The Balkanids as an instance of back-arc thrust belt: possible relation with the Hellenids. — *Geol. Soc. Amer. Bull.*, 85; 1077-1084.
- Boccalletti, M., Manetti, P., Peccerillo, A., Stanisheva-Vassileva, G. 1978. Late Cretaceous high-potassium volcanism in Eastern Srednogorie, Bulgaria. — *Geol. Soc. Amer. Bull.*, 89, 439-447.
- Bončev, E. 1978. Geotectonic position of the Balkanides. — *Geologica Balc.*, 8, 1; 23-40.
- Boyantov, I., Dabovski, C., Gočev, P., Harkovska, A., Kostadinov, V., Tzankov, Tz., Zagorčev, I. 1989. A new view of the Alpine tectonic evolution of Bulgaria. — *Geologica Rhodopica*, 19, 1; 107-121.
- Chatalov, G. A. 1988. Recent development in the geology of the Strandzha zone in Bulgaria. — *Bull. Techn. Univ.*, Istanbul, 41; 433-465.
- Dimitrov, Str. 1956. Die kinetische Regionalmetamorphose der jurassische Ablagerungen und Leucogranite in Südostbulgarien. — *Abh. XX Inter. Geol. Kongr.*, Mexico, 2; 326-333.
- Dimitrov, Str. 1958. Über die alpidische Regionalmetamorphose und ihre Beziehungen zu der Tektonik und dem Magmatismus in Südostbulgarien. — *Geologie*, 7, 3-6; 560-568.
- Dimitrov, Str. 1959. Kurze Übersicht der metamorphen Komplexe in Bulgarien. — *Freiberger Forschungshefte*, C 57; 62-72.
- Hsü, K. J., Nachev, I. K., Vuchev, V. T. The evolution of Bulgaria in light of plate tectonics. — *Tectonophysics*, 40, 3-4; 245-256.
- Nachev, I. K. 1978. On the Upper Cretaceous basin model in the Srednogorie zone. — *C. R. Ac. bulg. Sci.*, 31, 2; 213-216.
- Nachev, I. K. 1982. Basin models of flysch in Bulgaria. — *Палеонтология, стратиграфия, литология*, 16; 61-72.
- Nachev, I. K. 1986. Origin of flysch and submarine volcanism. — In: *Достижения българской геологии*. С., Техника; 21-26.

Fig. 4. Metallogenic scheme of the recent gold-bearing placers in the Eastern Srednogorie (Strandža-Sakar): 1—9, like on Fig. 1; 10 — Sakar type of granite "batholithe"; 11 — Sakar type Triassic — metaconglomerates, metasediments, silicate crystalline schists and marbles (according to Чаталов, 1985₂); 12 — Late Cretaceous, Grudovo group of sediments (small particles to block breccia — olistostromes with packets of sandstones, aleurites, marls and clayey limestones) and volcanites (basalts, trachybasalts and basalt-trachyandesite) in effusive, explosive and subvolcanic facies (according to Geological Map of Bulgaria, 1/500000, 1989); 13 — Late Eocene — conglomerate-mollusc at places and marine coal-bearing sediments (breccia-conglomerate-sandy, coal-bearing-bituminitic etc. formation) (according to Geological Map of Bulgaria, 1/500000, 1989); 14 — plio-quaternary — gold-bearing alluvial and lacustrine-alluvial placers (according to data from the heavy concentrate sampling and more systematic prospecting exploration activities, submitted kindly by P. Toparev, Committee of Geology); a — single indications; b — area anomalies and relatively higher concentrations

- Nachev, I. K. 1989. Paleogeodynamics of Alpine flysch on the Balkans. — *Geologica Balc.*, 19, 3; 23-39.
- Precambrian in Younger Fold Belts (European Variscides, the Carpathians and Balkans)* (Eds. V. Zoubek, J. C. Cogné, D. Kozhoukharov, H. G. Kräutner). 1988. John Wiley & Sons, N. Y.; 885 p.
- Savov, S. 1985. Structural features of Bogdanovo-Slivovo anticline (Oman part of North Strandza). — *Geologica Balc.*, 15, 4; 41-60.
- Sengör, A. M. C. 1985. The story of Tethys: How many wives did Okeanos have? — *Episodes*, 8, 1; 3-12.
- Sengör, A. M. C. 1987. Tectonics of the Tethysides: Orogenic collage development in a collision setting. — *Ann. Rev. Earth Plan. Sci.*, 15; 213-244.
- Stanisheva-Vassileva, G. 1980. The Upper Cretaceous magmatism in Srednogorie zone, Bulgaria: A classification attempt and some implications. — *Geologica Balc.*, 10, 2; 15-36.
- Vassileff, L. 1971. Antemagmatic magnetite ores with Mg-skarns from intermediate depths in the Kroumovo deposit, Bulgaria. — In: *Proceedings of the IMA-IGOD Meetings, Tokyo, IAGOD Volume*, 381-386.
- Vassileff, L., Stanisheva-Vassileva, G. 1981. Metallogeny of the Eurasian copper belt: Sector Bulgaria. — *Geologica Balc.*, 11, 2; 73-87.
- Vassileff, L., Stanisheva-Vassileva, G. 1988. Porphyry copper systems as markers of the Mesozoic-Cenozoic active margin of Eurasia. — *Tectonophysics*, 154; 167-169.
- Vassileff, L., Stanisheva-Vassileva, G. 1991. Petrochemical and geodynamic correlation of the porphyry copper systems in the Eurasian Copper Belt: The segment Romania — Pakistan. — *Geologica Balc.*, 21, 3; 3-34.
- Адами, Ш., Гамкрелидзе, И. П., Закарпадзе, Г. С., Лордкипанидзе, М. Б. 1974. Аджаро-Триалетский прогиб и проблема образования глубоководной впадины Черного моря. — *Геотектоника*, 1; 78-97.
- Бахнева, Д., Стоев, Л., Деков, Д., Христов, С. 1988. Метасоматични изменения в антимонитовото рудопроявление Доброселец, Тополовградско. — *Год. ВМГИ*, 34, 1; 115-122.
- Бончев, Е. 1940. Алпидски тектонски прояви в България. — *Сп. Бълг. геол. д-во*, 12, 3; 155-247.
- Бончев, Е. 1986. *Балканидите, геотектонско положение и развитие*. С., БАН. 274 с.
- Бончев, Е., Савов, С., Чаталов, Г. 1969. Върху блоковото разчленяване на Странджанския антиклинорий. — *Изв. геол. инст., сер. геотектоника*, 18; 143-158.
- Василев, Л. 1979. Парагенези на магнетитовата интра- и перимагматична рудоносна формация на редица в Странджа планина. — *Сп. Бълг. геол. д-во*, 40, 1, 109-114.
- Василев, Л. 1982. Средногорската зона като металогенно понятие. — *Геохим., минерал., петрол.*, 16; 77-92.
- Василев, Л. 1982. Металлоформации в Болгарии — опыт классификации. — *Geologica Balc.*, 12, 3; 3-21.
- Василев, Л. 1989. Литосферни плочи и металогенния в България. — *Сп. БАН*, 1; 45-53.
- Василев, Л. 1990. До- и постакреционна металогенния в Болгарии (Тезиси). — *Geologica Balc.*, 20, 3, 72.
- Василев, Л., Станишева, Г. 1963. Илменито-титаномангнетитовото орудаване във Великовския плутон при с. Кости, Странджа планина. — *Сп. Бълг. геол. д-во*, 24, 1, 1-20.
- Василев, Л., Станишева-Василева, Г. 1972. Регионална вертикална зоналност на хидротермалните орудавания в Бургаския синклинорий. — *Сп. Бълг. геол. д-во*, 33, 2, 123-131.
- Василев, Л., Стайков, М. 1991. Краткая металогенния Болгарии. Объяснительная записка к металогенической карте масштаба 1 : 1 000 000. — *Сп. Бълг. геол. д-во*, 52, 2, 1-55.
- Василев, Л., Станев, И. 1991. Признаки альпийской аккреционной металогеннии в Юго-Восточной Болгарии. — *Geologica Balc.*, 21, 4; 16.
- Дабовски, Хр., Харковска, А., Каменов, Б., Маврудчиев, Б., Станишева-Василева, Г., Чунев, Д., Янев, Й. 1989. *Карта альпийского магматизма Болгарии (геодинамический подход)*. С., КИИП по картография.
- Димитров, Ц., Каменов, Б. 1941. Титаномангнетитът в Манастирските височини. — *Год. Дир. прир. богатства*, 1; 105-112.
- Йосифов, Д. С., Мирлин, Е. Г., Валяшко, Г. М., Пчеларов, В. Г., Брусиловский, Ю. Б. 1986. Возможная фаза спрединга в развитии Средногорского рифта (по геофизическим данным). — *Geologica Balc.*, 16, 1; 3-14.
- Каменов, Б. 1976. Петрология на Желязковския плутон. — *Год. Соф. унив., геол.-геогр. фак.*, 67, 1; 179-212.
- Каменов, Б., Вергилов, В., Генов, И., Савов, С., Дабовски, Х., Нвчинова, Л., Вергилов, П., Андреев, А. 1986. Геоложки строеж и петро-

- графски особености на Лесовския ортометаморфен комплекс. — В: *Странджанско-Сакарски сборник*, 4, 8. С., ЦИНТИ; 336—345.
- Кожухарова, Е., Кожухаров, Д. 1974. Докамбрийски метаморфизирани дайкови магматити от Димитровградско и южните склонове на Сакар планина. — В: *Микерогенезис*, С., БАН; 379—386.
- Лилов, П. 1990. Rb-Sr и K-Ag датирование Сакарского гранитоидного плутона. — *Geologica Balc.*, 20, 6; 53—60.
- Лилов, П. 1986. Изотопни данни за възрастта и топлинното въздействие върху Сакарския гранитов плутон и неговата рамка. — В: *Странджанско-Сакарски сборник*, 4, 8. С., ЦИНТИ, 355—362.
- Монов, Б., Монахов, И., Владов, Й. 1971. Прояви на триаски вулканизъм в Западния Предбалкан. — *Сп. Бълг. геол. д-во*, 32, 1; 33—45.
- Начев, И. 1980. Моделът на островните дъги и алпийската еволюция на България. — *Сп. Бълг. геол. д-во*, 41, 3, 230—246.
- Начев, И. 1986. Къснокредна еволюция на българските земи. — *Сп. Бълг. геол. д-во*, 47, 1, 19—31.
- Недялков, Н. 1964. Изследвания върху триаския магматизъм в областта на Св. Илийските височини. — В: *Сб. Й. Йосцев, С.*, Техника; 743—767.
- Недялков, Н. 1983. Нови данни за природата на Сазлийския разлом. — *Геотект., тектонофиз., геодинам.*, 16; 43—50.
- Недялков, Н. 1988. Разломная сеть в Восточно-Марицком бассейне. — В: *Линеаменты как структуры сочленения разновозрастных складчатых областей и их металлогении*. С., БАН; 125—141.
- Пальшин, И. Г., Скендеров, Г. М., Божков, И. Б., Михайлов, Я. Н., Котов, Е. И., Бедринов, И. Т., Иванов, И. М. 1989. Нови геохронологични данни за кимерските и алпийските магмени и хидротермални образувания в Средногорската и Старопланинската зона в България. — *Сп. Бълг. геол. д-во*, 50, 2; 75—92.
- Панайотов, В. 1968. Върху ролята на структурния и литоложки контрол при локализиране на скарно-магнетитовите орудявания в района на Манастирските възвишения. — *Изв. НИГИ*, 3; 93—105.
- Савов, С. 1961. Косите разломи в Югоизточна Странджа. — *Год. Упр. геол. проучвания*, 11; 73—77.
- Савов, С. 1962. Тектоника на Южна Странджа. — *Приноси геол. Бълг.*, 1; 253—298.
- Савов, С. 1983. Строеж на Елховското структурно понижение. — *Сп. Бълг. геол. д-во*, 44, 3; 326—331.
- Станишева-Василева, Г. 1986. Магматическая эволюция в Восточно-Среднегорской вулканической области в верхнемеловом периоде — тезисы современной концепции. — *Geologica Balc.*, 16, 1; 84.
- Станишева-Василева, Г. 1989. Восточно-Среднегорская вулкано-интрузивная область. — В: *Альпийский магматизм Средногории и Восточных Родоп и связанная с ним металлогения*, XIV Конгр. КБГА. С., БАН; 27—46.
- Станишева, Г., Василев, Л. 1966. Сенонските трахиандезити и тяхната алкална автометасоматоза. — *Изв. НИГИ*, 3; 283—310.
- Стоев, Л., Деков, Д., Дедински, Л. 1986. Данни за наличието на антимонитова минерализация в района на Манастирския грабен — Ямболско. — В: *Странджанско-Сакарски сборник*, 4, 8. С., ЦИНТИ; 389—391.
- Стоев, Л., Деков, Д., Дедински, Л., Пальшин, И., Драгоманов, Л., Стоянов, М., Скендеров, Г. 1986. Особенности на геоложкия строеж на до-неогеновата подложка в Ямбол-Елховския басейн. — В: *Странджанско-Сакарски сборник*, 4, 8. С., ЦИНТИ; 320—329.
- Стоев, Л., Деков, Д., Дедински, Л. 1989. Золоторудная минерализация в районе села Доброселец, Тополовградского района. — *Докл. БАН*, 42, 6; 83—84.
- Тектонски строеж на България* (Йосцев, Й., ред.). 1971. С., Техника; 558 с.
- Чаталов, Г. 1961. Триаски кристалини шисти и гранитите, вложени в тях в областта на селата Светлина, Градец и Мъдрец, северно от Сакар планина. — *Сп. Бълг. геол. д-во*, 22, 1; 80—86.
- Чаталов, Г. А. 1973. Кондоловска структурна полоса и Странджанска лобовая линия. — *Докл. БАН*, 26, 10; 1379—1382.
- Чаталов, Г. А. 1985. Принос към стратиграфията и литологията на палеозойските и триаските скали в Светицлийските височини. — *Сп. Бълг. геол. д-во*, 46, 1, 53—70.
- Чаталов, Г. А. 1985. Принос към стратиграфията и литологията на Сакарския тип триас (Сакар планина, Югозападна България). — *Сп. Бълг. геол. д-во*, 46, 2; 127—143.
- Чаталов, Г. 1985. Стратиграфия юрской системы в Странджанской области в Болгарии. — *Geologica Balc.*, 15, 4, 3—41.
- Чаталов, Г. 1990. Геология на Странджанската зона в България. С., БАН; 263 с.
- Шиляфова, Ж., Шиляфов, Г. 1986. Неметални полезни изкопаеми в Сакар планина. — В: *Странджанско-Сакарски сборник*, 4, 8. С., ЦИНТИ; 248—258.

- Я н е в, Й., Б а х н е в а, Д. 1980. Алпийският магматизъм на Карпато-Балканската област в моделите на тектониката на плочите. — В: *Геодинамика на Балканите*. С., Техника; 63—75.
- Я н е в, С. 1987. Палеозойска ератема. — В: *Геоложки предпоставки за нефтогазоносността на Североизточна България*. С., Техника; 13—40.
- Я н и ш е в с к и й, А. А. 1947. К вопросу о возрасте кристаллических сланцев и изверженных пород Южной Болгарии и основные черты ее геологического строения. — *Сп. Бълг. геол. д-во*, 15—19; 107—148.