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General correlation of the Late Palaeozoic sequences in the Balkans and the Caucasus

Balkanlarda ve Kafkaslardaki Üst Paleozoyik istiflerinin genel karşılaştırması

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ABSTRACT

This paper presents a brief correlation of the Late Palaeozoic (mainly Late Carboniferous-Permian) sequences and volcanism in the Balkans and Caucasus. It is possible to correlate lithological and facial carracteristics of the Upper Palaeozoic sections in both of the regions, mainly for the continental, subaereal and shallow marine molasses from the Balkan Peninsula and Northern parts of the Caucasus, being the Fore-Range, Bechasin or Laba-Malka (the Northern slope of the Great Caucasus), Main Range, Southern slope of the Great Caucasus, Southern and Northern Transcaucasus. The comparable Upper Carboniferous and Permian sequences of the Caucasus and Balkans may be related to the Variscan orogeny and its neighbouring lowlands. The formation of the orogen was a result of the continent-continent collision between some peri-Gondwanan terranes and the southern periphery of the East-European platform. In the Caucasus, the continental and arc-related and oceanic ridges are also identified. The distribution and relationships of the continental, transitional and shallow-marine facies in the eastern Balkans and Western Caucasian zones indicate the presence of a marine basin within the present-day Black sea during the Late Palaeozoic. The reconstruction of the Late Palaeozoic palaeogeography and palaeogeodynamics is important, as it represents the final period of the Palaeozoic compressional and/or transpressional events before the dominance of the new extensional regime that started in the latest Permian or Triassic time. The Caucasus and Balkans, belonging to the same Alpine-Himalayan belt, are situated at the junction of the Eurasian and Africa-Arabian plates between the European and Asiatic segments of the belt. In the present configuration, the continent-continent collisional zone of the Eastern Mediterranean represents an accretionary collage of fragments (terranes) of Euroasiatic, Tethyan and Gondwanian origin.

Keywords: Balkan Peninsula, Caucasus, Late Palaeozoic, palaeogeodynamics, palaeogeography, Tethys, Variscan orogeny.

ÖZ

Son yıllarda yapılan çalışmalar, Balkanlardaki ve Kafkaslaların kuzeyindeki; özellikle Küçük Kafkaslar, Bachasin veya Laba-Malka (Büyük Kafkasların K yamacı), Büyük Kafkaslar, Büyük Kafkasların G yaması, G ve K Transkafkasya alanlarındaki Üst Paleozoyik istiflerinin litolojik ve fasiyes açısından korelasyonunun mümkün olduğunu göstermektedir. Karşılaştırılabilir nitelikteki bu Üst Karbonifer ve Permiyen birimleri Varisken Orojenik zonu ve buna komşu alanlarda gelişmiştir. Bu orojenez bazı peri-Gondwana kökenli mikrolevhalarla Paleo-Avrupanın G kenarı (D Avrupa Platfor-

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mu) arasındaki kıta- kıta çarpışması ile ortaya çıkan yığışmanın ürünüdür. Kafkaslarda kıta ve okyanus adası şelfleri, bunların kıta yokuşu ve yamaç birimleri, yay ardı basenleri, volkanik yayları ve okyanus ortası sırt oluşumları ayırtlanabilmektedir. D Balkanlar ve B Kafkaslardaki kıtasal ve sığ denisel fasiyeslerin dağılımı ve ilişkileri Geç Paleozoyikte, bugünkü Karadenizin obduğu alanda, denizel bir basenin varlığına işaret etmektedir. Öte yandan Geç Paleozoyik paleocoğrafyasının yeniden kurgulanması jeodinamik açıdan da önem kazanmaktadır. Zira bu dönem Paleozoyik sıkışmalı veya transpresyonal evresinin sonunu ve Permiyen sonu-Triyas'ta hakim olan yani bir gerilmeli rejimin başını temsil etmektedir. Balkanlar ve Kafkaslar, Alp-Himalaya kuşağı üzerinde, Avrupa va Asya segmenteri arasında, Avrasya va Afroarabistan litosferik levhalarının sınırında yer alırlar. Doğu Akdeniz kıta-kıta çarpışma kuşağının bu günkü konfigürasyonunda bu birimler Euroasiyatik, Tetis ve Gondwana kökenli mikrolevhaların yığışması ile ortaya çıkan bir karışığı temsil ederler. Bu çalışmada, Balkanlarda ve Kafkaslardaki Geç Paleozoyik (esas olarak Geç Karbonifer-Permiyen) sedimentasyon ve volkaniszma olaylarının kısa bir özeti sunulmakta ve jeodinamik anlamda yorumlanmaktadır.

Anahtar Kelimeler: *Balkan Yarımadası, Geç Paleozoyik, Kafkaslar, paleojeodinamik, paleocoğrafya, Tetis, Varisken Orojenezi.*

INTRODUCTION

The Eastern Balkans and the Caucasus, situated on both sides of the Black Sea and representing parts of the Alpine-Himalayan mountain belts, may be used successfully for geological correlation between the European and Asiatic segments of the belt. Investigations of the last 25 years by the International Geological Correlation program (IGCP), namely, Project 5 "Pre-Variscan and Variscan events in the Alpine-Mediterranean mountain belts", Pr. 198 "Evolution of the Northern margin of the Tethys", Pr. 276 "Palaeozoic geodynamic domains and their alpidic evolution in the Tethys", Pr. 499 "DEVEC" – "Devonian land sea interaction: evolution of ecosystems and climates" and other projects, gave, in this connection, valuable results.

In different publications the Carboniferous and Permian in the Caucasus had been supposed to exist but the system was firstly established with paleontological evidence by Gamcrelidze et al. (1963) and in other subsequent papers. The Carboniferous and the Permian in Bulgaria was discused at the end of the 1870's by Toula (1877, 1881), but the Permien was not proven and was nominated as "Permian-Carboniferous" by Bonchev (1955). Tenchov and Yanev (1963) interpreted the data of Minčev et al. (1962), for a part of the Carbonoferous rocks, as Permian sediments. Later Yanev and Tenchov (1976, 1978) found other Permian deposits with flora.

LITHOTECTONIC ZONES OF THE CAUCASUS AND BALKANS

The Upper Palaeozoic of the Caucasus

Carboniferous-Permian deposits are known from all the main tectonic zones of the Caucasus (Figure 1). There are: 1. The Laba-Malca (or Bechasin) Zone (LMZ), of the Northern slope of the Great Caucasus (GC); 2. The Fore-Range Zone (FRZ) of the Northern slope of the GC; 3. The Main Range Zone (MRZ) of the GC; 4. The Southern Slope Zone (SSZ) of the GC; 5. The Dzirula salient (DSZ) of the Northern Transcaucasus (NTZ); 6. The Loki and Murguz salients of the Southern Transcaucasus (STZ); 7. The Lesser Caucasian (LCZ) ophiolitic suture zone; and 8. The Nakhichevan block (NBZ). The following formations are present: 1. Ophiolites (LCZ); 2. Back arc basin sediments (SSZ); 3. Island arc volcanics (NTZ and STZ); 4. Continental shelf sediments (LMZ); 5. Terrestrial and shallow marine molasses (FRZ, LMZ, MRZ).

The Bechasin or Laba-Malka Zone

The nappe structure of the Bechasin Zone's Pre-Alpine basement has been determined. In the southern part of the LM Zone, continental molasse of Late Carboniferous-Permian age occurs locally, resting unconformably on the older rocks, (Figure 2, column C1).

The Fore-Range Zone

According to modern concepts, the Fore-Range Zone is a system of nappes (Omelchen-

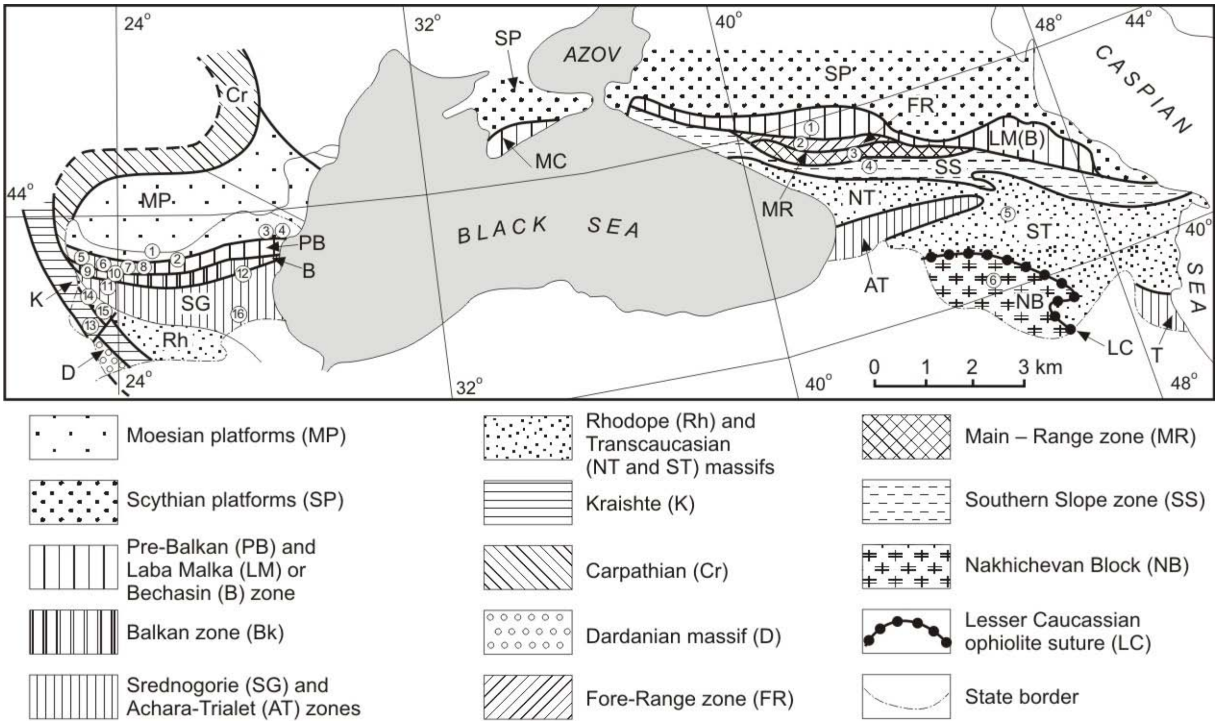

Figure 1. Main tectonic units of the Eastern Balkans and the Caucasus.
Legend: 1. Moesian (MP) and Scythian platforms (SP); 2. Pre-Balkan (PB) and Laba Malka (LM) or Bechasin (B) zones; 3. Balkan zone (B); 4. Srednogorie (SG) and Achara-Trialet (AT) zones; 5. Rhodope (R) and Transcavcasian (NT and ST) massifs; 6. Kraishte (K); 7. Dardan massif (D); 8. Fore-Range Zone (FR); 9. Main Range Zone (MR); 10. Southern Slope Zone (SS); 11. Nakhichevan Block (NB); 12. Lesser Caucasian ophiolite suture (LC); 13. State boundary. Numbers on the map (1-6 in the Caucasus and 1-18 in the Balkans) indicate the location of selected stratigraphic sections.

Şekil 1. Doğu Balkanlar ve Kafkasların ana tektonik birlikleri
Açıklamalar: 1. Moesya platformu (MP) ve Sikitiyen platformu (SP); 2. Ön-Balkan (PB) ve Laba Malka (LM) or Beşasin (B) zonları; 3. Balkan zonu (B); 4. Srednogoya (SG) ve Acara-Triyalet (AT) zonları; 5. Rodop (R) and Transkafkasya (NT and ST) massifleri; 6. Kraişte (K); 7. Dardan massifi (D); 8. Ön-Kuşak Zonu (FR); 9. Ana Kuşak Zonu (MR); 10. Güney Yamaç Zonu (SS); 11. Nahcevan Bloğu (NB); 12. Küçük Kafkas Ofiyolit Süturu (LC); 13. Ülke sınırları. (Haritadaki sayılar (Kafkaslarda 1-5 ve Balkanlarda 1-18) seçilmiş olan kesitlerin yerlerini göstermektedir.

ko & Belov, 1983) composed of sedimentary, volcanic and plutonic Lower-Middle Palaeozoic rocks. The period of major nappe formation is the Early-Middle Carboniferous (end of Tournaisian - beginning of Visean). The nappe structure is covered by unconformable Upper Palaeozoic deposits (neoautochthon). In the Fore-Range Zone, the Upper Palaeozoic neoautochthonous complex is in a discordant position over the underlying Middle Palaeozoic (Figure 2, col. C2), and is unconformably overlain by the Lower Jurassic sediments. In the eastern part of this zone, the Lower Triassic molasse series is gradational from the Upper Palaeozoic. In the western part of the same zone, the Permian and Triassic, represented by marine facies, belong to a quasiplatform cover. The Upper Carboniferous consists of conglomerates (with pebbles of crystalline rocks, granites, quartz-porphyries and quartz), sandstones and agrillites, whereas the Middle Carboniferous (which is finer grained) comprises coal seams and rhyolitic volcanics. The Permian of the Fore-Range Zone includes a thick series of continental red molasses interbedded with high-K calc-alkaline dacitic and andesitic volcanics. Marine calcareous and terrigeneous facies related to the Upper Permian crop out in the western part of the zone, the latter resting conformably on red beds or discordantly with older rocks.

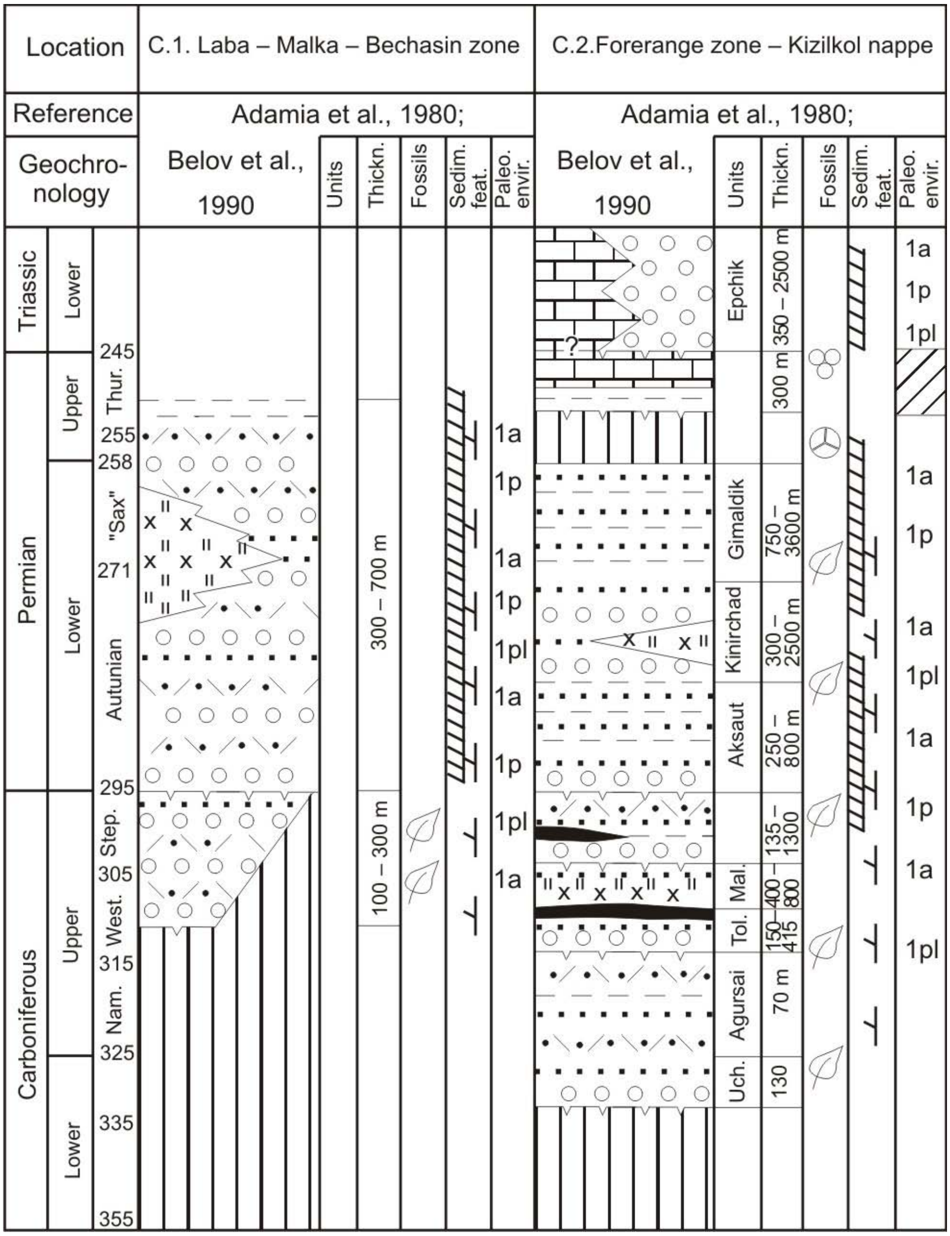

Figure 2. Stratigraphic columnar sections of the Upper Paleozoic sequences of the Northern Caucasus, Laba – Malka-Bechasin zone C1 and Forerange Zone C2 (Kızılkol Nappe).

Şekil 2. Kuzey Kafkasların seçilmiş Üst Paleozoyik stratigrafik sütün kesitleri, Laba –Malka-Beşasin zonu (C2) ve Ön-Kuşak Zonu Kızılkol napı (C2).

The Main Range Zone

The stratigraphic knowledge of the pre-Jurassic deposits in the Main Range Zone has not changed significantly since the studies of Adamia et al. (1980). In this area, the Middle and Upper Carboniferous and the Permian are represented by marine and continental molasses, transgressively overlying metamorphic and magmatic complexes (Figure 3, col. C3). In the coal-bearing Middle Carboniferous molasses, rhyolitic volcanics occur. The Late Palaeozoic volcanism in the Greater Caucasus, associated with accumulations of terrestrial and shallow-water molasse, took place in Middle Carboniferous-Permian times. The Middle Carboniferous volcanics are attributed to a continuous andesite-

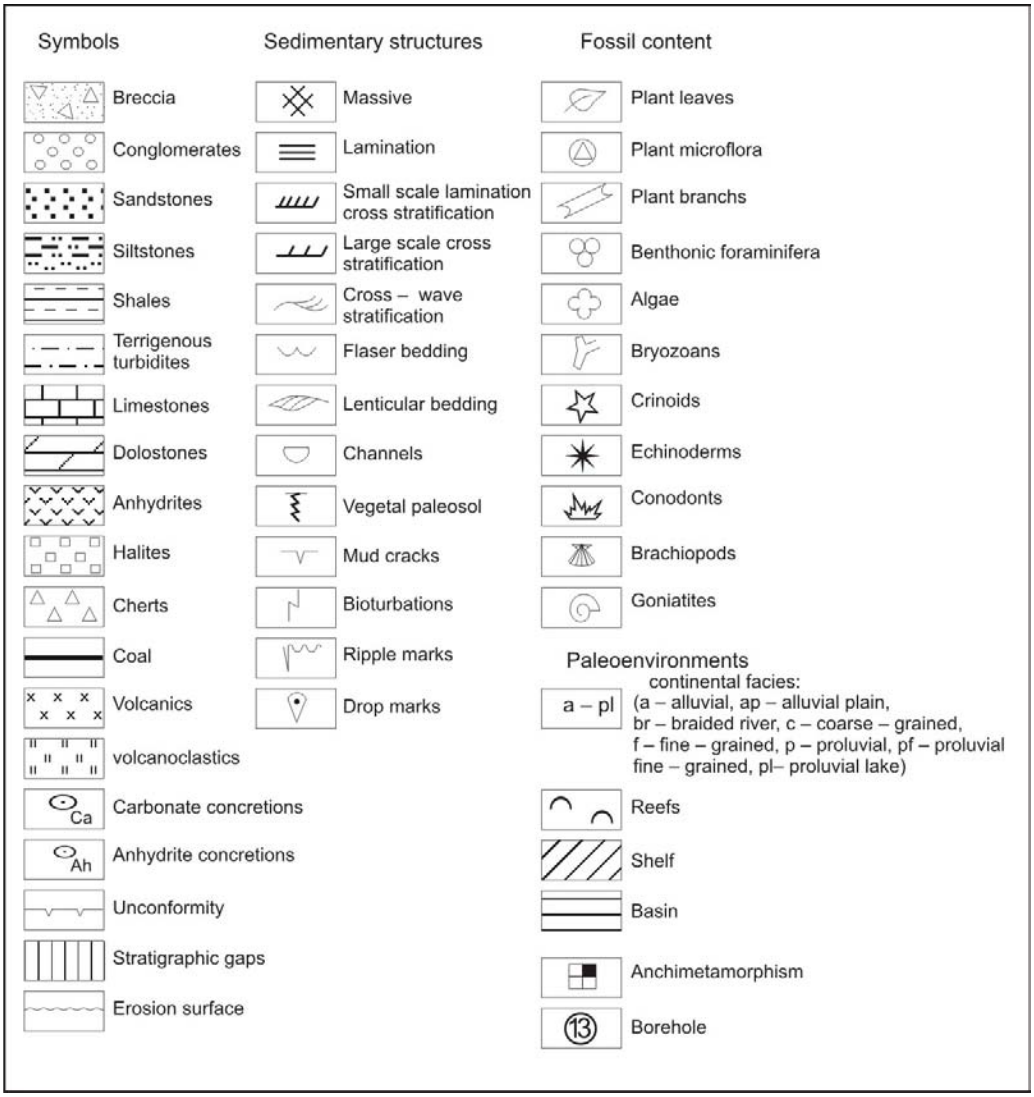

Figure 2 (devamı). Legend for Fig. 2-8. Symbols: 1 – breccia; 2 – conglomerates; 3a – sandstones; 3b – greywacks; 4 – siltstones; 5 – shales; 6 – terrigene turbidites; 7 – limestones; 8 – dolostones; 9 – anhydrites; 10 – halites; 11 – cherts; 12 – coal; 13 – volcanics; 14 – volcanoclastics; 15 – carbonate concretions; 16 – anhydrite concretions; 17 – unconformity; 18 – stratigraphic gaps; 19 – erosion surface; 20–32 – sedimentary structures: 20 – massive; 21 – lamination; 22 – large skale cross stratification; 23 – small scale lamination cross stratification; 24 – cross-wavy stratification; 25 – flaser bedding; 26 – lenticular bedding; 27 – chanels; 28 – vegetal paleosol; 29 – mud cracks; 30 – bioturbations; 31 – ripple marks; 32 – drop marks; 33-43 – fossil content: 33 – plant fronds; 34 – plants microflora; 35 - plants branchs; 36 – benthonic foraminifers; 37 – algae; 38 – bryozoans; 39 – crinoids; 40 – echinoderms; 41 – conodonts; 42 – brachiopods; 43 – goniatites; 44-47 – paleoenvironments: 44 – continental (a- alluvial; ap – alluvial plain; br – braided river; c – coarse grained; f – fine grained; p – proluvial; pf – proluvial fine grained; pl – proluvial lake); 45 – reefs; 46 - shelf; 47 – basin; 48 – anchimetamorphism; 49 – borehole.

Şekil 2 (contd.) Şekil 2 den 8' e kadar semboller: 1 – breş; 2 – konglomera; 3a – kumtaşı; 3b – grovak; 4 – silttaşı; 5 – şeyl; 6 – terijen türbidit; 7 –kireçtaşı; 8 – dolotaşı; 9 – anhidrit; 10 – halit; 11 – çört; 12 – kömür; 13 – volkanit; 14 – volkanoklastit; 15 – karbonat yumruları; 16 – anhidrit yumruları ; 17 – uyumsuzluk; 18 – stratigrafik boşluk; 19 – erozyon yüzeyi; 20–32 – sedimanter yapılar: 20 – massif; 21 – laminasyon; 22 – büyük ölçekli çapraz tabakalanma; 23 – küçük ölçekli çapraz tabakalanma; 24 – dalgalı çapraz tabakalanma; 25 – flaser tabakalanma; 26 – merceksi tabakalanma; 27 – kanal; 28 – bitkisel paleosol; 29 – çamur çatlağı; 30 – biyoturbasyon; 31 – dalga kırışığı; 32 – damla izi; 33-43 – fosil: 33 – bitki gövdesi; 34 – bitki mikroflorası; 35 - dal; 36 – bentik foraminifer; 37 – alg; 38 – briyozoa; 39 – krinoid; 40 – ekinoderm; 41 – konodont; 42 – brachiopods; 43 – goniatites; 44-47 – paleoenvironments: 44 – continental (a- aluvial; ap – aluvial düzlük; br – örgülü nehir; c – kaba taneli; f – ince taneli; p – proluvial; pf – proluvial ince taneli; pl – proluvial göl); 45 – resif; 46 - şelf; 47 – basen; 48 – ankimetamorfizma; 49 – sondaj.

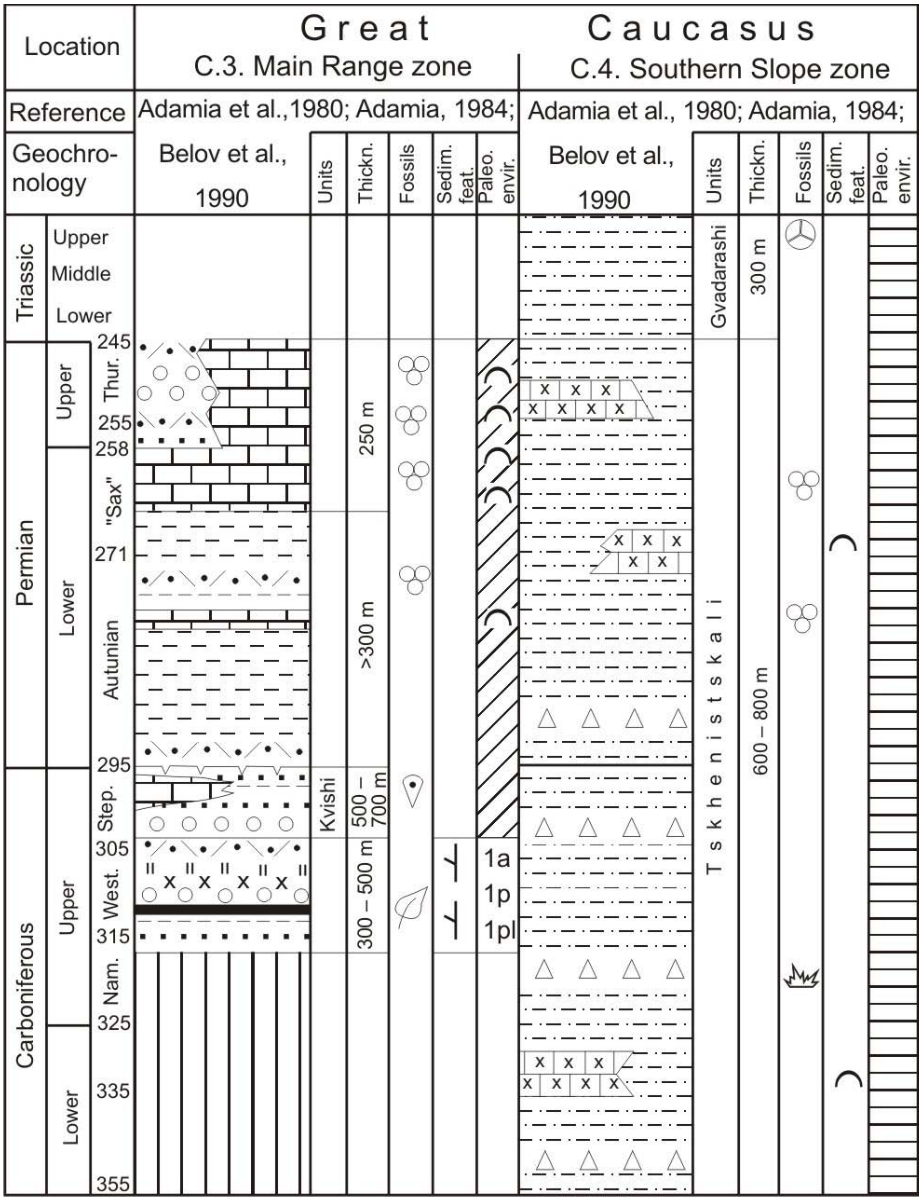

Figure 3. Stratigraphic columnar sections of the Upper Paleozoic sequence of the Great Caucasus: Main Range (C3) and Southern Slope (C4) zone.

Şekil 3. Büyük Kafkasların seçilmiş Üst Paleozoyik stratigrafik sütün kesitleri Ana Kuşak Zonu (C3) ve Güney Yamaç Zonu (C4).

dacite-rhyolite series. The Lower Permian volcanics are represented by aggregates of basic, intermediate and acid composition, whereas the Upper Permian rocks are characterized by somewhat higher alkalinity, and by trachytic, trachy-andesitic and trachy-dacitic compositions. The Permian volcanics are assigned, on the whole, to a continuous basalt-andesite-dacite-rhyolite magmatic series with appreciable predominance of an acid component.

The Southern Slope Zone

In the Southern Slope Zone, the Palaeozoic and Triassic crop out only in the central part and are represented mainly by sandy argillaceous turbiditic deposits with cherts and lenses of organogenic limestones (Dizi series, Figure 3, col. C4).

The Dizi Group is a continuous section of Devonian-Triassic clastics consisting of phyllites, clay shales and sandstones with interbeds of gritstone and, less frequently, conglomerates and cherts (with radiolarians), lenses of crinoidal and reef limestones, olistostromes and a thin volcanic member of intermediate composition. Facies analysis of the sediments indicates their accumulation near the continental rise, and land situated to the south (the Transcaucasus) appears to be their source area. The rates of sediment accumulation (30-40 mm/1000 years) are close to those in the present-day marginal seas.

The Transcaucasian Zone

The Palaeozoic stratigraphy of the Transcaucasian massif has been interpreted on the basis of the three salients in its basement: the Dzirula (Northern Trancaucasus), the Khrami and the Murguz (southern Transcaucasus). Upper Palaeozoic rocks are known on the Khrami uplift of the Artvin-Bolnisi block, where volcanic sequences bear Bashkirian flora (Figure 4, col. C5). In the lower part of the section, reef limestones with brachiopoda, corals, foraminifera and

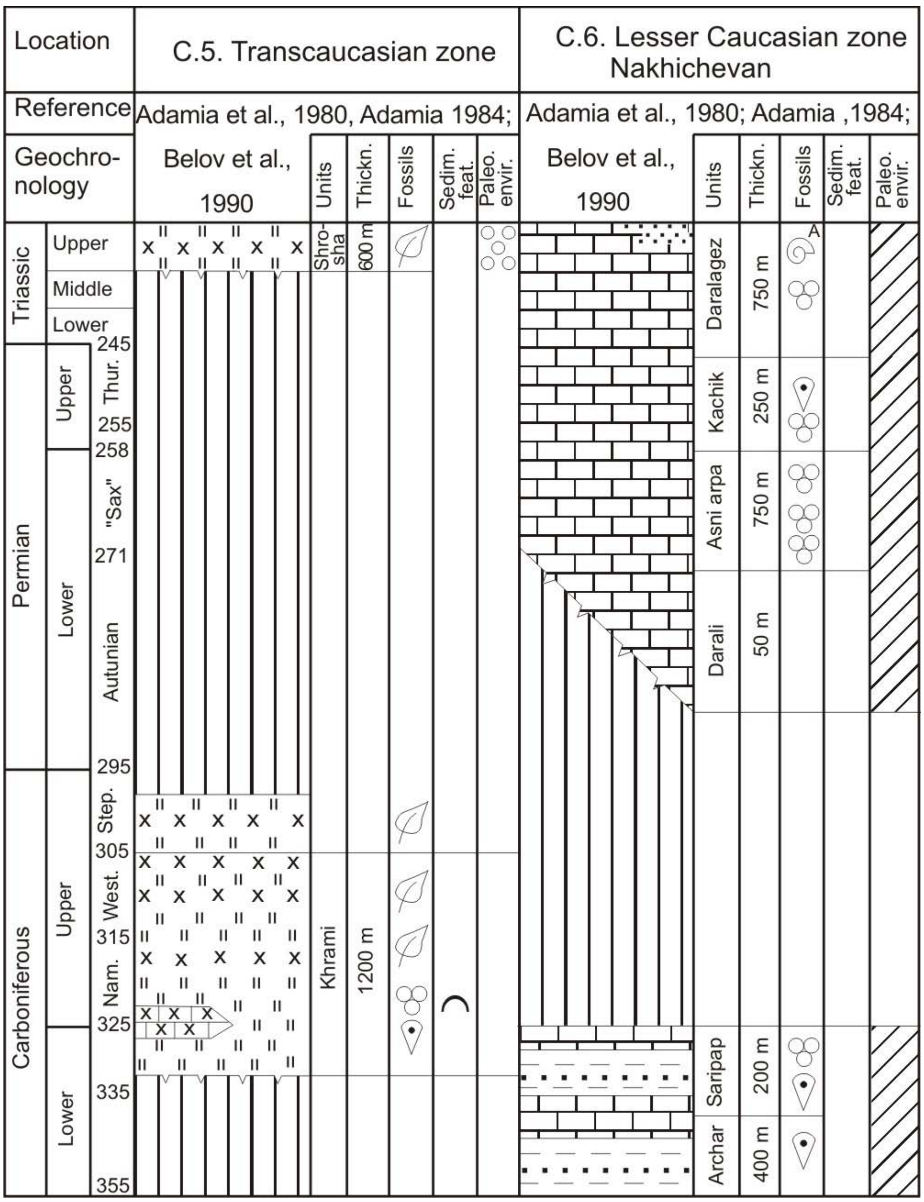

Figure 4. Stratigraphic columnar sections of the Upper Paleozoic sequence of the Transcaucassus (C5) and Lesser Caucasus (C6).

Şekil 4. Transkafkas (C5) ve Küçük Kafkasların (C6) seçilmiş Üst Paleozoyik stratigrafik sütün kesitleri.

sponges of Late Visean - Namurian age crop out. Presumably Carboniferous rhyolitic volcanics are present also on the Dzirula massif (Georgian block). The Upper Palaeozoic volcanics and particularity those of the Khrami and Dzirula salients consist of homogeneous rhyolites. The character of their differentiation indicates that these rocks belong to the calc-alkali series. Volcanogenic deposits in the Murguz ridge are represented by terrestrial andesitic volcanics yielding a Middle – Upper Carboniferous flora, on the Khrami salient, by terrestrial and near-shore marine (rhyolitic) volcanics with an Upper Visean – Middle Carboniferous fauna and flora, and by quartz-porphyry (rhyolitic) lavas on the Dzirula salient.

The Lesser Caucasian ophiolite Zone

This zone separates the Palaeozoic-Early Mesozoic domain of subduction-related magmatism, metamorphism and deformation, belonging to the North Tethyan province, from the shallow marine domain consisting predominantly of carbonate sediments of the South Tethyan (Gondwanan) passive margin. The Lesser Caucasian (Sevan-Akeran) suture is built up of strongly tectonised dismembered Upper Palaeozoic-Mesozoic ophiolites (nappes and melanges) of root zone (Karijakin & Aristov, 1990). According to Zakariadze et al. (1988, 2000, 2007), mantle tectonites forming the matrix of the ophiolitic melanges are transitional between abissal peridotites and peridotites of active margin. Magmatic rocks are represented by subductional tholeiitic, boninitic and within-plate type volcanics. The Sm/Nd ages of the tholeiitic gabbro-norites are Triassic (226±0,3 - 224±6 m.a.). The Palaeontological age of the volcanics ranges from Late Palaeozoic and Triassic to Late Cretaceous (Adamia et al., 1987, Knipper, 1990).

The Lesser Caucasus Nakhichevan Block

The Iranian subplatform concept (part of the Palaeozoic Gondwanaland northern border) was proposed by Belov (1968). The part of the Caucasus bordering Iran is characterized by Palaeozoic sequences of passive continental margin type belonging in the past to Gondwana. This concerns the south of Armenia and Nakhichevan, the territory to the south of the ophiolitic zone of Izmir-Ankara-Erzincan-Sevan-Resht (Göncüoğlu et al., 1997). The Lower Carboniferous deposits of the Nakhichevan block rest conformably on Devonian ones. These are also marine terrigenous and carbonate sediments. The limestones are frequently bituminous, or organogenic-detrital, sometimes oolitic, rich with remains of foraminifera, corals and brachiopods of the Visean. Higher up, the eroded Devonian deposits are overlain by Permian and younger beds (Figure 4, col. C6).

The Upper Palaeozoic is represented here only by Permian deposits of submarine character. These are bituminous algal and algal-foraminiferal limestones, marls and clay shales. Based on palaeontological data, the lowermost part can be attributed to the Lower Permian, whereas the upper part corresponds to the Upper Permian. The Permian deposits are overlain without visible unconformity by Lower Triassic clay shales and marls.

THE UPPER PALAEOZOIC OF THE BALKANS

The Carboniferous and/or Permian deposits are known from different Alpine morphotectonic zones of the eastern part of the Balkan Peninsula: the Moesian Plate (Figure 5, columns 1-4), the Balkan Mountain System – Balkan range s.s. (Figures 6 - 7): the Fore Balkan Zone (Figure 6, columns 5-8), the Balkan Zone (Figure 7 columns 9-12), and the South Bulgaria Zone (Figure 8, columns 13-16); the last zone including the Strandzha Mountain to the SE) and the Kraishte Zone (Figure 8, columns 13 and 16). None of the Upper Palaeozoic deposits occur in the Thracian and Serbo-Macedonian massifs. In the other zones the Upper Carboniferous (Pennsilvanian) and Permian rocks are everywhere continental, with the exception of some areas near the Black Sea, where during limited time intervals some restricted areas have been filled by transitional, deltaic or evaporitic facies. Marine carbonate sediments of the Middle-Upper Visean and terrigeneous and coal-bearing deposits of the Uppermost Visean and Pennsilvanian deposits were established in deep boreholes in the Moesian Plate. Marine Lower Permian (Gi-

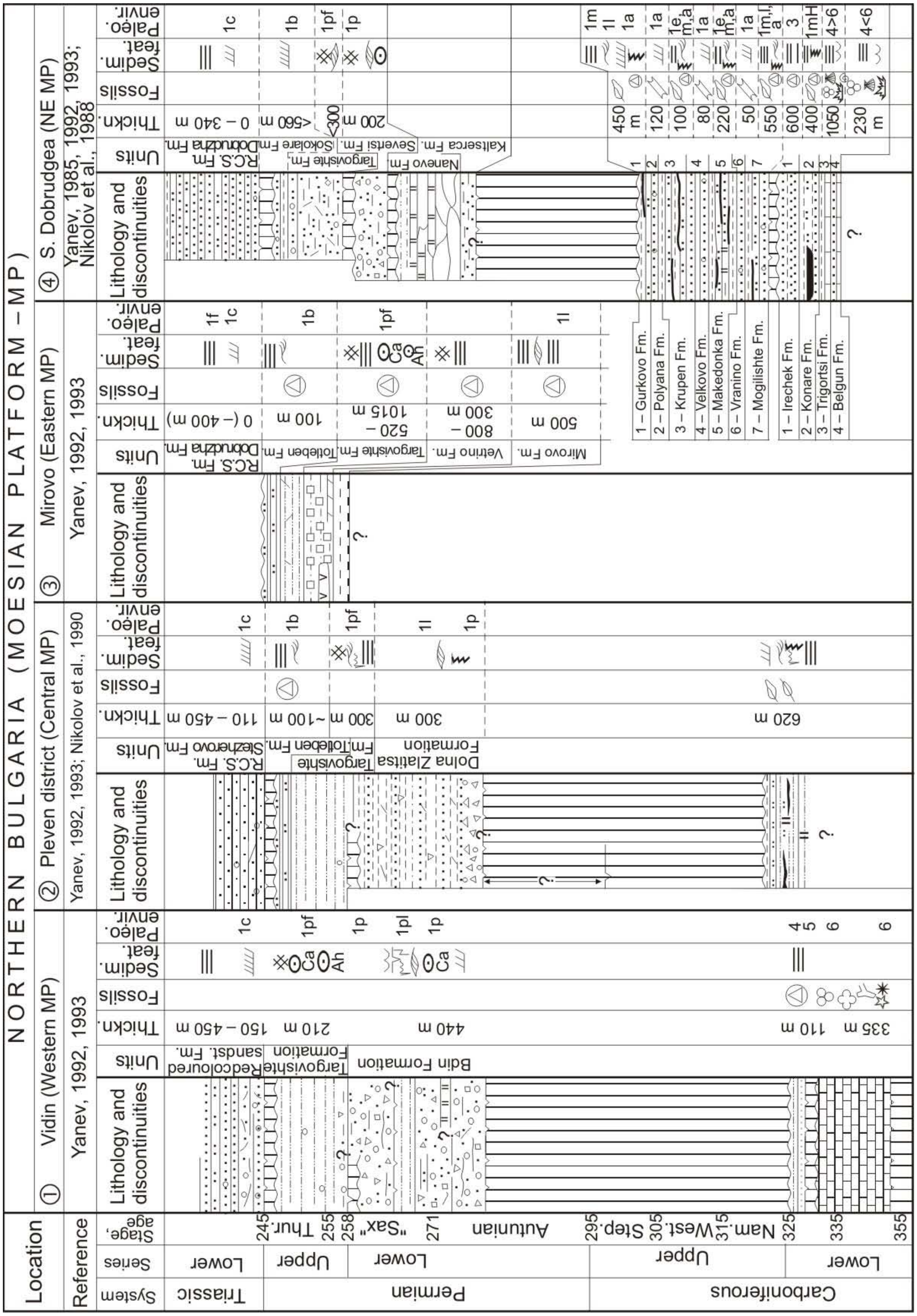

Figure 5. Stratigraphic columnar sections of the Upper Paleozoic sequences of Northern Bulgaria: 1. Vidin , 2. Pleven, 3. Mirovo, 4. South Dobrudzha.

Şekil 5. Kuzey Bulgaristanın seçilmiş Üst Paleozoyik stratigrafik sütun kesitleri: 1. Vidin, 2. Pleven, 3. Mirovo, 4. Güney Dobruca.

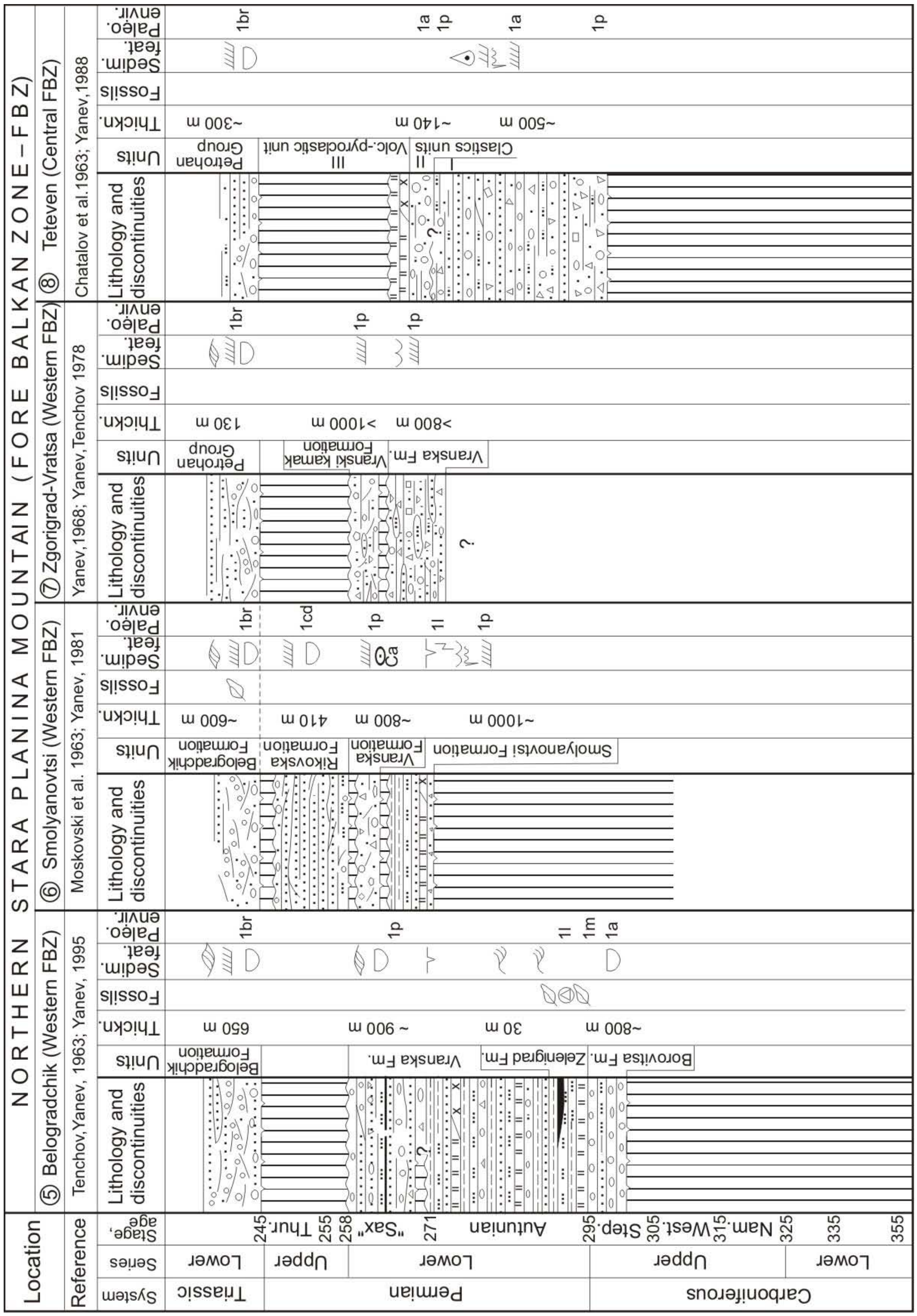

Figure 6. Stratigraphic columnar sections of the Upper Paleozoic sequences of the Northern Stara Planina (Fore Balkan), Bulgaria: 5. Belogradchik, 6. Smolyanotsi, 7. Zgorigrad-Vratsa, 8. Teteven.

Şekil 6. Kuzey Stara Planina'nın (Ön Balkan, Bulgaristan) seçilmiş Üst Paleozoyik stratigrafik sütun kesitleri: 5. Belgradcık, 6. Smolyanotsi, 7. Zgorigrad-Vratsa, 8. Teteven.

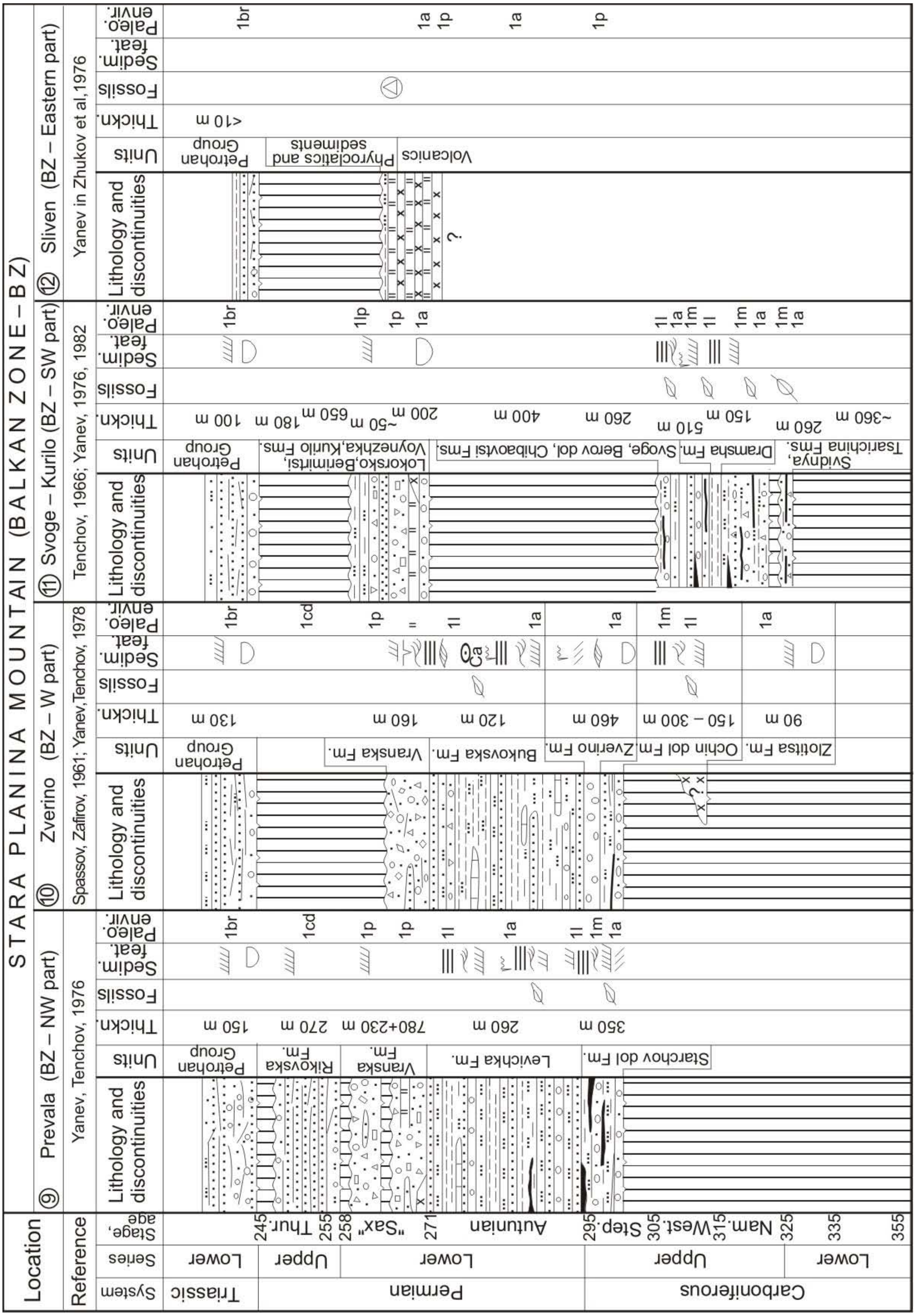

Figure 7. Stratigraphic columnar sections of the Upper Paleozoic sequences of the Stara Planina (Balkan s.s.), Bulgaria: 9. Prevala, 10. Zverino, 11. Svoge-Kurilo, 12. Sliven.

Şekil 7. Stara Planina'nın (Ana Balkan, Bulgaristan) seçilmiş Üst Paleozoyik stratigrafik sütun kesitleri: 9. Prevala, 10. Zverino, 11. Svoge-Kurilo, 12. Sliven.

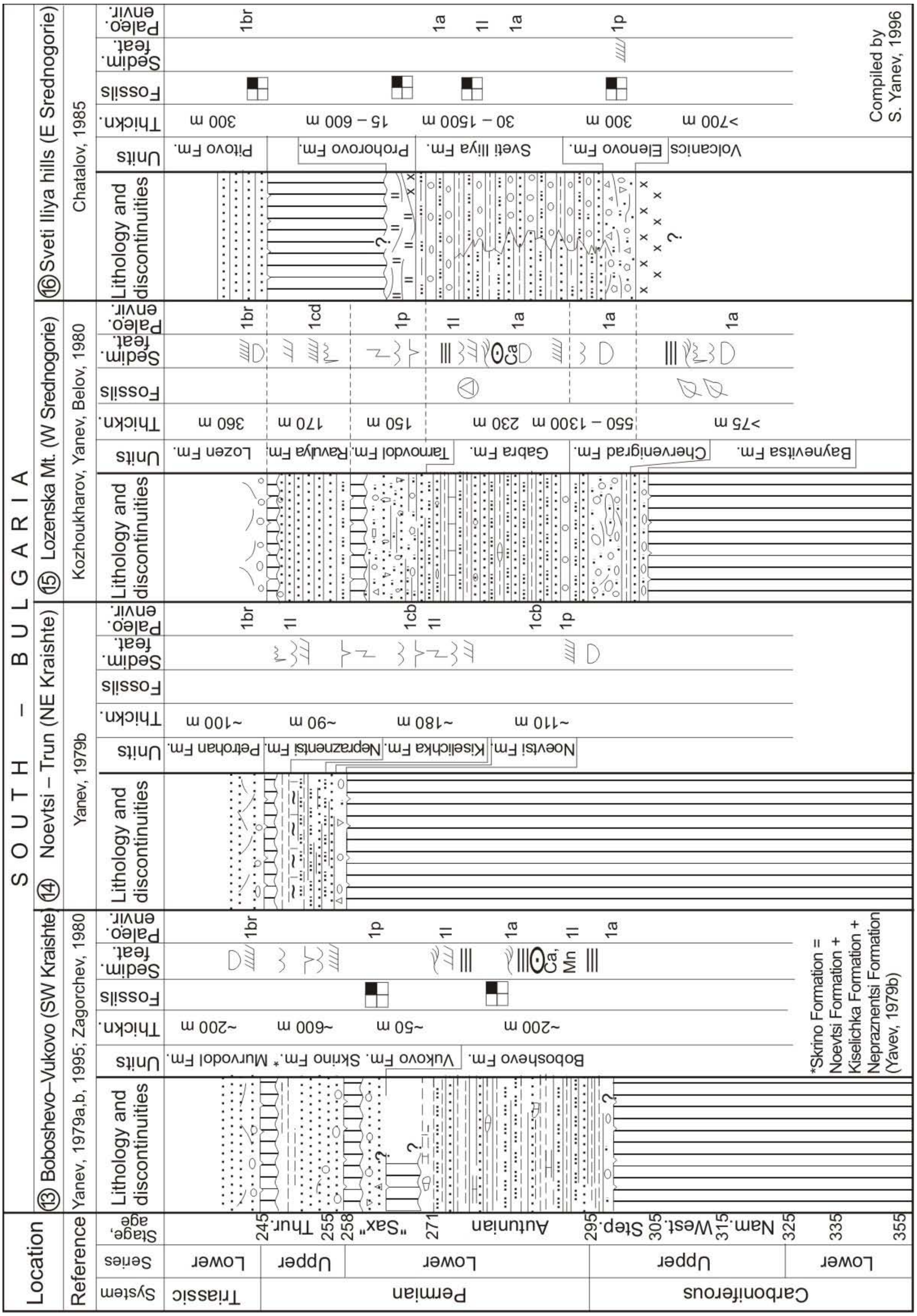

Figure 8. Stratigraphic columnar sections of the Upper Paleozoic sequences of South Bulgaria (Kraishte and Srednogorie): 13. Boboshevo-Vikovo, 14. Noevtzi-Trăn, 15. Lozenska Mt., 15. Sveti Ilia Hills.

Şekil 8. Güney Balkan'ın (Krayişte ve Srednagora) seçilmiş Üst Paleozoyik stratigrafik sütun kesitleri:13. Boboshevo-Vikovo, 14. Noevtzi-Trăn, 15. Lozenska Dagları., 15. Sveti Ilia Tepeleri.

suralian) sediments crop out only in the Strandzha Mountain. Volcanic activity took place during the Pennsylvanian-Gisuralian (Late Carboniferous - Early Permian). It is predominantly of subaereal type.

The distribution of the Upper Palaeozoic sediments and volcanics and their facies variety (as well as the main features of the Alpine evolution) was predetermined by the pre-Late Palaeozoic development of the Balkan region.

The presence of the three Gondwanan (s.l.) Palaeozoic terranes in the basement of the eastern Balkan Peninsula was documented by sedimentologic, palaeoclimatic, palaeobiogeographic and palaeomagnetic data. From north to south these are Moesian, Balkan and Thracian terranes, derived from different parts of Gondwana and Perigondwana.

According to the opinion of the Bulgarian author, some of the palaeogeodynamic environments mentioned in the Upper Palaeozoic of the Caucasus are also recognized in Bulgaria. The units similar to the Bulgarian ones are located in the northern zones of the Caucasus (Laba-Malka, Great Caucasian and Transcaucasian) however, some of them occur in the Pre-Upper Palaeozoic basement of the different Bulgarian terranes.

The Ophiolites of the Thracian Suture

The ophiolitic rocks of oceanic origin (MORB ophiolites) on the boundary between the Moesian and Balkan terranes, and between the Balkan and Thracian terranes (along the Thracian suture) are Vendian in age (Haydoutov, 1987; Von Quadt et al., 1998). The island arc volcanics at the Northwestern periphery of the Balkan terrane (along the same suture) are Cambrian in age (520±5Ma after Von Quadt et al., 1998). The magmatism from the Balkan and Central Srednogorie sectors of the Balkan terrane is Variscan in age (Carrigan et al., 2005; Peytcheva et al., 2004; Peytcheva et von Quiadt, 2004).

The Sediments in and Around the Variscan Orogen

The Namurian-Stephanian and Permian sediments in the Balkan terrane (Figure 7, column 11 and Figure 8, col. 14 and 15) overlie the palaeontologicaly dated Upper Devonian-Lower Carboniferous turbidites with layers of cherts, olistostromes and limestones. The Upper or Middle Permian (Guadalupian-Gisuralian?) deposits overlie also organogenic limestones with layers of cherts, palaeontologically dated as Lower Devonian. These rock assemblages form the basement of the Upper Palaeozoic sequences and source area for the Upper Palaeozoic clastics.

The various regional data show a movement in echelon of the Moesian and Balkan (and Thracian?) terranes from the Southern humid zone to the Northern arid zone during the Permian. In NW Bulgaria (part of the Moesian terrane), the erosional surface over different rocks of the Upper and/or Middle Devonian is overlain by Upper Carboniferous (Pennsilvanian) polydetrital and algal-foraminiferal limestones formed in shallow-water conditions (Janev, 1972; Yanev, 1985). The same sediments and conditions persisted there, locally, also during the Middle-Late Visean, and migrated to the territory of NE Bulgaria. During the Latest Visean, tectonic movements occurred and dry land was formed, which, after a depositional break affected the whole of Northern Bulgaria, supplied terrigeneous and clay-terrigeneous materials in neritic conditions. The marine basin withdrew to the East at the end of the Visean, and clastic rocks were deposited upon a delta formed in south Dobrudgea. It was partially swamped and gradually retreated to the east while, in south Dobrudgea, paralic sediments within the Namurian - Westphalian interval were replaced by limnic clastics (Figure 5, columns 1-4) and coal-bearing sediments, which occurred as river-bed (lower course), terrace, lacustrine, palustrine and other facies (Yanev, 1982a, 2000; Yanev at al., 2001; Nikolov et al., 1988, 1990).

Collisional Sedimentation and Volcanism

The collisions between the Moesian, Balkan and Thracian terranes took place during the Late Carboniferous and Permian (Yanev, 1991, 1997; Haydoutov and Yanev, 1997). The Late Palaeozoic collisional coarse molasse sedimentation took place at variable relief in predominantly continental conditions (Figure 5 and 6, columns 5-12). The collision between the Thracian and Balkan terranes is documented not only by the features of the sediments and volcanics, but also by the collisional magmatism (the so called “south Bulgarian granitoid formations”), the absolute age of which, according to Rb/Sr and others' determination, ranges from 342±27 - 337±14 Ma to 320-300 Ma (Zagorchev and Moorbath, 1986; Peytcheva et al., 2004). The collision between the Balkan and Moesian terranes is also marked by collisional magmatism of the “Stara Planina granodiorite formation”, 360-310 Ma and 280-240 Ma, (U/Pb determination by Amov et al., 1981). The building of the Variscan orogen is related to the collision and accretion of various terranes.

Clastic material was supplied to fault-bounded Late Carboniferous (Pennsylvanian) and Early Permian (Gisuralian-Guadelupian) basins from the accretionary prism of the Variscan Orogen and Thracian terrane (the “Thracian massif”). The clastic material was accumulated in grabens and semi-grabens located within the orogen (Yanev, 1970) as well as within the extensive sedimentary basins situated to the north and east of Variscan chain and around the Thracian massif. Three main domains of continental sedimentation developed in the eastern part of the Balkan Peninsula (present-day territory of Bulgaria and Serbia) during the whole Late Palaeozoic age. The chain of the Variscan Orogen extending from the NW to SE across Bulgaria was formed, and to the north and south of the chain the lowland sediments were deposited. During the Namurian-Westphalian and Late Stephanian-Earliest Permian (“Autunian”), within intermountain valleys as well as along their border, firstly limnic clastic, shaly and coal-bearing sediments were deposited also as river-bed (upper course), terrace, lacustrine, palustrine and other facies (Janev, 1969, 1988; Yanev, 1989). They were followed by proluvial cones and playa-lake sediments, deposited during the late “Early Rotliegendes” and “Late Rotliegendes” (Yanev, 1981, 1982b). During the Late Permian the systems of two large continental basins (to the north and south of the Variscan chain) developed. Within the whole domain of the Balkan domain, the Permian system can be divided into two well-differentiated sedimentary groups (cycles) separated by a marked unconformity.

The first group — Upper Stephanian - Lower Permian (“Pensssilvanyan-Gisuralan”) consists of lacustrine, fluvial and proluvial fan deposits, accompanied by acid to medium acidic calc-alkaline (dacite-andesite) volcanics (Figure 7, col. 15-16). They were accumulated in intermountain and deep grabens or semigrabens. The boundary faults generally have WNW-ESE trends and often coincide with long-lived tectonic structures, which became re-active as late as the Alpine orogeny.

The second group (Upper Permian = Guadelupian-Lopingian) is represented by deltaic and continental clastics and belongs only to the SE of the Moesian domain (Provadia depression) – by halite and sulphate evaporites (zones to the west and to the north of Varna). These deposits form a widespread blanket which covers both basins of the first group and the surrounding highs. The duration of tectonic control is documented by strong changes in the thickness, ranging from a few meters to more than 1200 m. The halite-bearing sedimentation was linked with sabkha conditions, and the sulphate-bearing sediments with lagoonal environments. Both evaporitic basins have clear terminations to the north, west and south and have been connected to salt-bearing marine water to the east – to the zone of the modern Black Sea basin.

Shallow-marine Succession

In Strandzha Mountain the shallow-marine Gisuralian succession overlies Palaeozoic granites (Malyakov and Bakalova, 1978). The base is composed of black sandy shales with individual siltstone intercalations, which are followed upwards by gray dolomites, black shales and 60-70 m white, crystalline limestones hosting an abundant microalgal flora. The marine Permian sediments have a position near the Black Sea basin. The same is also valid when comparing the geographic situation and palaeogeographic affinities of the shallow-marine Upper Permian (Guadelupian-Lopingian?) limestones with foraminifers found as redeposited pebbles in the Mesozoic olistostrome in Eastern Rhodopes (Trifonova and Boyanov, 1986). The revealed foraminifers are a species widespread in the Upper Permian of the Caucasus and in some other areas (Taurus Montains in Turkey, Greece, Pamirs, Indochina, etc.).

Different varieties of volcanic, volcanoclastic and subvolcanic rocks have been described in many localities of the Balkan Peninsula (Yanev, 1981 and others, Carrigan et al., 2005). There are regions with thick volcanogenic successions or very big extrusive bodies in the Balkan (s.l.) (Sliven, Sveti Ilia Hills, West- and Central Stara Planina Mountain) and Moesian Plate (Tyulenovo, Vassil Levski, Ravna Gora and other boreholes). In Bulgaria the Late Variscan volcanism began in the Westphalian and ceased in the Gisuralian ("Lower Rotliegendes"). The Lower Permian ("Gisuralian") volcanics are represented by calc-alkaline rocks of median and acid composition. The Triassic volcanic rocks in the area of Vratsa and coastal Dobrogea are characterized by somewhat higher alkalinity, and volcanics of trachytic, trachyandesitic, trachy-dacitic and latitic composition are widespread (Vaptsarova et al., 1979, Cortesogno et al., 2004). The respective volcanics can be interpreted not as "subsequent" volcanism, but as an initial one belonging to a new Alpine (or Cimmerian) volcano-tectonic cycle.

COMPARISION OF CAUCASIAN AND BULGARIAN UPPER PALAEOZOIC SEQUENCES

The Late Palaeozoic sequences of the Caucasus and Bulgaria bear many similar important features. The formations similar to the Bulgarian ones are located just within the northern zones of the Caucasus (Bechasin or Laba-Malka, Great Caucasian and Transcaucasian). These formations, like those within Bulgarian territory, are related to European Variscides. However, the Caucasus also hosts Upper Paleozoic terranes of Tethyan (ophiolitic suture of the Lesser Caucasus) and South Tethyan (Nakhichevan terrane) origin. The other important peculiarity of the Caucasus is the presence of Upper Palaeozoic turbidites of the Dizi Series within the Southern Slope of the Great Caucasus (back-arc basinal formation of the Southern Slope Zone).

All the sedimentological and volcanological peculiarities of the rocks and successions in the Bechasin and Fore-Range zones are similar to the molasse sedimentation in the Balkans. For the latter, transition from the Upper Palaeozoic to Triassic was not observed, whereas in the eastern part of the FRZ Upper Palaeozoic sediments grade into Lower Triassic molasse series. Also, only calc-alkaline volcanics are characteristic for the Balkan Stephanian-Lower Permian molasses (Cortesogno et al., 2004a), while continental red molasses interbedded with "high-K calc-alkaline" dacitic and andesitic volcanics are reported for the FRZ. Within the zone, Upper Permian calcareous and terrigenous facies crop out in its western part. However, similar facies have not been found within Bulgaria. There are, however, re-deposited pebbles from Upper Permian limestones in some younger (Mesozoic) formations in South Bulgaria. Anorogenic volcanism in the Triassic sequences has been found only at the boundary of the Moesian plate (Cortesogno et al., 2004b).

The coal-bearing Upper Carboniferous molasses with volcanics and pyroclastics occur in the Main Range Zone and in the Balkans. The Upper Carboniferous sections of both regions in large scale are similar. In the Balkans, marine and deltaic sediments are met only in the Lower Carboniferous and Namurian A, while in the MRZ, the upper part of the Middle, the whole Upper Carboniferous and the Permian are represented by marine and continental molasses. The Upper Palaeozoic magmatic series are characterized by an appreciable predominance of an acid component, whereas within the Balkans volcanic rocks are absent in the Upper Permian (Lopingian). In the FRZ, they are present in the Upper Permian and characterized by somewhat higher alkalinity: trachyte, trachyandesite and trachydacite. In the Balkans, K-alkaline rocks have been established only in the Triassic sequences. In some places of the Balkans, paleobasalt-andesitic (porphyritic) formations associate with pre-Stephanian deposits.

It is not possible to indicate a Balkan analogue of the Caucasian Dizi Group. But some similar rocks are determined in different stages and series in South-Western Bulgaria. These are: shales, crinoidal and other limestones with chert layers and a thin volcanic member of intermediate composition – in Lower Devonian; sandy-argillaceous turbiditic deposits with cherts (with radiolarians), lenses of organogenic limestones and olistostromes – in Upper Devonian and Lower Carboniferous (Mississippian). There are sandstones with interbeds of gritstone and less frequently conglomerates in the upper part of the Permian of the same zone.

There are many data from the boreholes in the Moesian plate for Visean limestones with foraminifers, algae, corals, bryozoans, brachiopods, etc. which can be compared with the rocks and faunas on the Khrami uplift of the Artvin-Bolnisi block. There are some similarities between the Lower-Upper Carboniferous fauna and flora on the Dzirula salient and the Upper Visean-Upper Carboniferous flora in the Dobrugea basin, and between the terrestrial and near-shore marine volcanics in these regions.

The Nakhichevan block of the Lesser Caucasus has no equivalent in the Balkans, because it is a part of the Palaeozoic Gondwanaland northern border (Iranian subplatform), while the Balkan terranes are fragments of Peri-Gondwana. Nevertheless, it is very interesting to note that the age of the faunas determined in the Bulgarian Strandzha Mountain are known from the Lower Permian marine sediments in the Nakhichevan block.

In some recent Russian publications (Nikishin et al., 2004; Fokin and Nikishin, 2004), a new but unsuccessful attempt to compare the Upper Palaeozoic from the Caucasus and the south parts of Eastern Europe has been made.

The recent studies of the Balkan Peninsula and Caucasus by local scientists (e. g. Yanev, 1990, 1992; Karamata, 2006; Zakariadze et al., 2007) in cooperation with Turkish geologists (see Yanev et al., 2006; Göncüoğlu et al., 2006) renounce the theoretical supposition (e.g. Kalvoda et al., 2002) of a connection between the Moesian and Istanbul Terranes, and the Brunovistulian Terrane.

INTERPRETATIONS AND DISCUSSION

The continental sedimentation and volcanism in the Balkans and Caucasus was developed locally during the Late Carboniferous and spread progressively during the Permian. Lithological and facial comparisons of the Upper Palaeozoic sections in both regions are possible, especially, for the continental, subareal and shallow marine molasses from the Balkan Peninsula and analogical sediments outcropping in some specific parts of the Caucasus: the southern parts of the Fore Range Zone, and Laba-Malka Zone (mainly on the Northern slope and in the Main Range Zone of the Great Caucasus), as well as in Southern and Northern Transcaucasus. The comparable Upper Carboniferous and Permian rocks and successions of the Caucasus and Balkans are related to the Variscan orogen and its neighboring lowlands and to the passive continental margin. The formation of the Variscan orogen resulted from accretion during the continental (continent-continent) collision between some peri-Gondwanan terranes and the southern periphery of the Palaeo-Europe (East-European platform). In both regions, sediments were accumulated in grabens and semi-grabens within the continental orogenic belts, forelands of the orogenic mountain ranges (Figure 9), and continental lowlands (mainly sediment bypass zones), and they contain fluvial, lacustrine, palustrine, proluvial, playa-lake, lagoon, sabkha and other facies and collisional magmatics. In the Caucasus, deposits of the continental and island shelf, its slope and rise, marginal seas, back arc basins, deep-sea, island arcs and mid-oceanic ridges can also be identified. Therefore, the Upper Palaeozoic includes rocks related to oceanic environments and an active continental margin. The co-existence of products of oceanic, transitional and continental type crust is explained by the development of the so called "independent Mediterranean stage of the continental margin evolution" (Andieva, 2000). It is characterized by intercalating structure elements and sedimentary complexes which are typical of both passive and active margins, and a collision stage finished the evolution cycle – as a combination of a deep marine depresion of different age,

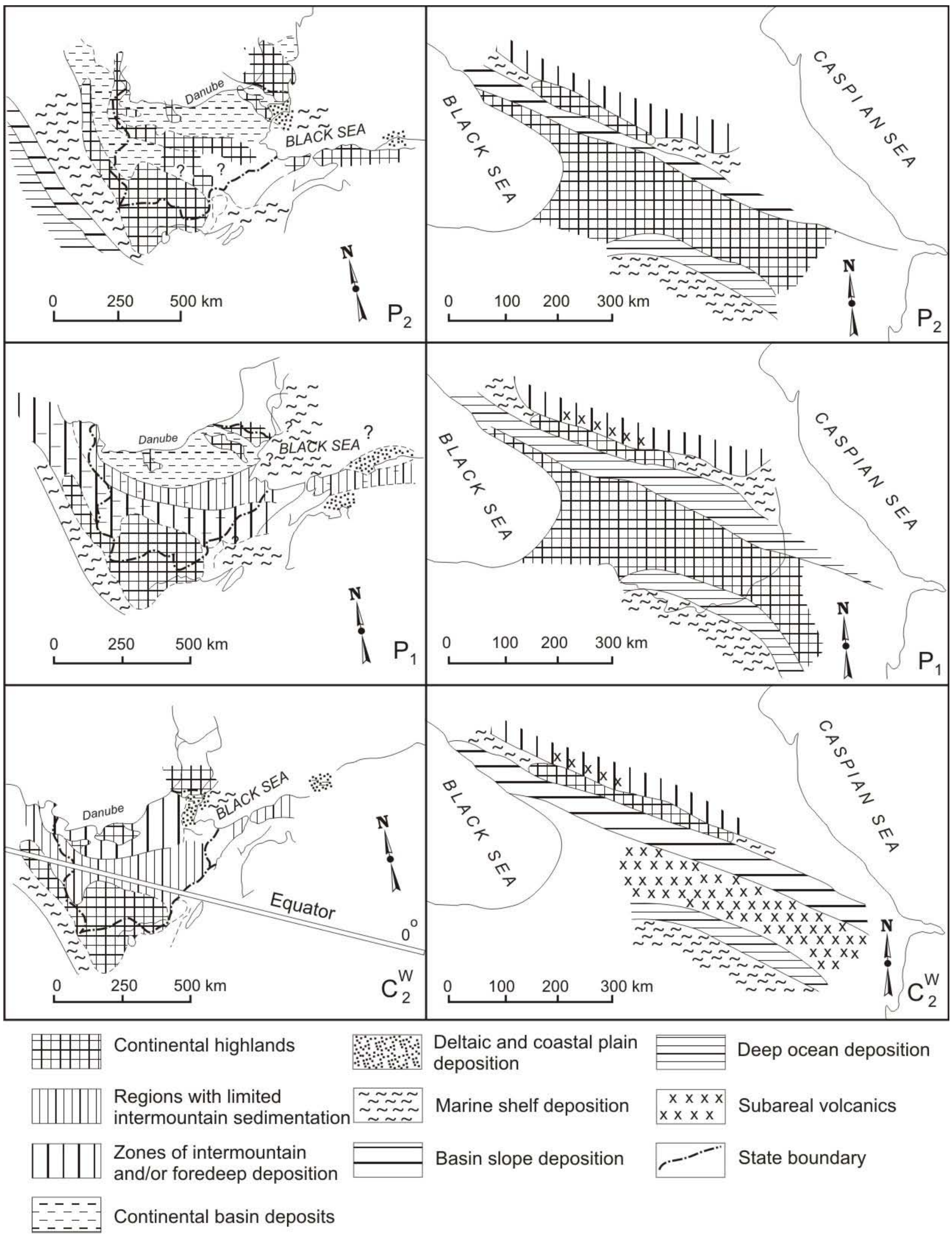

Figure 9. Comparative lithofacial schemes for Caucasus (1C, 2C, 3C) and part of South-Eastern Europe 1B, 2B, 3B) during the Westphalian (C2w), Early Permian (P1) and Late Permian (P2). Legend: 1 – continental highlands (zone without deposition, sediment source); 2 – continental highlands with intermontane (very limited) basin; 3 – continental intermontane and/or fordeep basins; 4 – continental basin deposition; 5 – deltaic and coastal plaine basins; 6 – marine shelf basins; 7 – basin or slope deposition; 8 – deep ocean deposition basin; 9 – sub-aereal volcanics; 10 – equator; 11 – state boundaries.

Şekil 9. Vestfaliyen (C2w), Erken Permiyen (P1) ve Geç Permiyen'de (P2) Kafkasların (1C, 2C, 3C) ve GD Avrupa'nın bir bölümünün (1B, 2B, 3B) litofasiyes korrelasyonu. Açıklamalar: 1 – kıtasal yükselimler (çökelmesiz kaynak alanlar); 2 – kıtasal yükselimler (dağarası basenlerde sınırlı çökelim); 3 – kıtasal dağarası ve/veya önülke çökelimi; 4 – kıtasal basen çökelimi; 5 – delta ve kıyı ovası çökelimi; 6 – denizel şelf çökelimi; 7 – basen veya yamaç çökelimi; 8 – derin okyanusal çökelim; 9 – karasal volkanizma; 10 – ekvator; 11 – ülke sınırları.

represented by back arc or residual oceanic basins, island arc structures, developed passive margins, young orogens and new-formed rifts. Another explication of the distribution of the Upper Palaeozoic in Caucasus can be an accretion of rocks from primary different palaeogeographic zones during the Variscan or/and Alpine tectonic movements.

In the Balkans, the Upper Palaeozoic continental molasses in some places are also in the immediate vicinity of oceanic and island arc magmatites and sediments. But this vicinity is related to a tectonic position of older rocks (along the Thracian suture) or to collisional accretion during the younger tectono-magmatic events (for the ophiolites of the Vardar zone). In many places, the present close position of these formations is related to the collisional accretion of Gondwanan, North Tethyan, Tethyan and South Tethyan terranes.

CONCLUSION

The Caucasus and the Balkans, which belong to the Alpine-Himalayan belt, are situated at the junction of the Eurasian and Africa-Arabian lithospheric plates between the European and Asiatic segments of the belt. In the present-day structure of the continent/continent collisional zone of the Eastern Mediterranean, they represent an accretionary collage of fragments (terranes) of Euroasiatic, Tethyan and Gondwanan origin.

Lithological and facial comparisons of the Upper Palaeozoic sections are possible, especially for the continental, subaereal molasses of the Balkan Peninsula and the Caucasus. It is possible to compare the Upper Carboniferous continental clastics, Permian redbed continental molasses, dacitic-andesitic and rhyolitic calc-alkaline volcanics, marine Permian sediments of the Great Caucasus and Transcaucasus with the Strandzha succession (SE Bulgaria).

The Variscan orogenesis is related mainly to the formation of the continental crust over the former palaeoisland arc system of the northern margin of the Palaeotethys and/or is due to the collisional accretion between different Gondwanan (s.l.) terranes. Calc-alkaline volcanics (with a predominance of dacites and rhyolites) accumulated in subaereal or shallow-marine conditions, together with continental and transitional coal-bearing and evaporitic molasses that were widely distributed throughout this area.

The distribution and relationships of the continental, transitional and shallow-marine facies in South Dobrudgea, the Provadia depression, Strandzha Mountain, and the Fore Range and Transcaucasian zones indicate the presence of a marine basin in the present-day Black sea basin during the Late Palaeozoic. The reconstruction of Late Palaeozoic palaeogeography and palaeogeodynamics is very important because it is the last occurrence of Palaeozoic compresional and/or transpresional movements before the domination of the new extensional regime that started in the Triassic or during the Latest Permian.

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