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DIVERSIFICATION OF THE BALKAN FAUNA: ITS ORIGIN, HISTORICAL DEVELOPMENT AND PRESENT STATUS

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Abstract — The paper presents the specific history of the lithosphere, as well as the geomorphological and paleontological characteristics of the territory of South Europe and Mediterranean, as one of prerequisites of the adequate biogeographic, biome and ecosystem diversity of the Balkan Peninsula. Results of various studies on the biodiversity of certain categories of fauna as well as of general biodiversity of particular regions (i.e. countries) on the territory of Balkan Peninsula, conducted by different authors, point to the necessity of unifying the research methods and criteria used in these investigations. According to the author, the best solution would be a realisation of a adequate common research project on the geographical distribution of the biodiversity of the fauna on the Balkan Peninsula as a whole.

Key words: Balkan Peninsula, faunal diversification, evolution, ecology

INTRODUCTION

The remarkable richness of plant and animal species on the Balkan Peninsula represents a unique ecological and biogeographical phenomenon in Europe. The variety of regions, complex geological history, and interactions between populations, species, and ecosystems have all resulted in enormous diversity within the abundance of plants, animals, and ecosystems in this area. Not only are the vast number of endemic and relict species highly significant in themselves, but their different ecological characteristics, distribution and origin contribute to the region's uniqueness.

GEOMORPHOLOGICAL AND PALEONTOLOGICAL CHARACTERISTICS OF THE BALKAN PENINSULA

The history of the lithosphere of the Balkan Peninsula is unique and in many ways different from the history of other parts of the lithosphere, especially those of Northern Europe. Its main characteristic is that it belongs to the youngest regions of Europe (Neo-Europe), which were gathered into one entity only a few tens of millions of years ago and which had long been scattered over a much wider area before they were put together and added to the older parts of Europe. This means that Europe passed through several periods of enlargement (Pantić, 1996).

The enlargement of continents is one of the better examples which prove the existence of a process of permanent increase in the complexity and uniqueness of various states through geological history. An idea of the complex dynamics of the lithosphere is given by significant horizontal movement in segments of the Earth's crust, which has been proved using many scientific methods (paleomagnetism, paleobotany, etc.). It is absolutely clear that these horizontal movements, which have been traced in detail through the last 300 million years, provide explanations for the great changes in paleogeographical relations (i.e., origin of the Tethys and its evolution during Mesozoic times, its genesis and development of new mountain ranges, the ordering of biogeographical provinces, and – to some extent- climatic changes). In other words, explanations are given for the order of changes in states of habitats throughout this long geological period (Pantić, 1996).

The evolution of horizontal movements of the Earth's crust in Southern Europe during the Tertiary (in the period between 37 and 3 million years ago) is shown on Figs. 1 and 2. Six colored paleogeographic-palinspastic maps represent intervals from Late Eocene to Pliocene times for the circum-Mediterranean area (Rögl, 1998; Rögl and Steininger, 1983). These maps are based primarily on an updated biostratigraphic correlation of marine and continental biogeographic events, the transgression and regression cycles of these regions, and the facies distribution in the Central and Eastern Paratethys. The generally accepted models of plate tectonics and sea-floor spreading for the Mediterranean area have been taken into account.

Large parts of the continent were shaped during the last glaciation, which ended approximately 10,000 years ago. Much of Europe's soil was formed during this era in connection with the many inland ice periods. A characteristic feature of Europe is the Alpine ridge, a permanent divide in the continent for climate, history, and trade.

The given dynamics of the Earth's crust will help us to understand the basic geological and geomorphological state of our natural surroundings and help us understand the genesis of such an enormous number and variety of petrological (rocks and minerals), paleontological (plant and animal fossils), geodynamic, and geomorphological objects (Pantić, 1996). This specific history of all the relevant natural systems in geological time has left a very rich geo-heritage in the Balkan region. It can be safely said that the Balkan Peninsula is unique in the world as a treasure trove of geo-heritage.

Nowhere else in the Mediterranean area is the relief of the land more complicated than on the Balkan Peninsula (Cvijić, 1904; Stanković, 1960). Several great geotectonic units exist: first, the great Rhodopian mass should be distinguished as the ancient crystalline nucleus of Hercynian age that occupies the central part of the Balkan Peninsula. This resistant nucleus of the Peninsula, formed mainly of crystalline schists with intrusions of eruptive rocks, has been greatly broken and disrupted by faultings into a number of depressions and isolated blocks, some of which reach more than 2,900 m in elevation and represent the highest summits of the Peninsula. The Rhodopes Range is succeeded in the north by the great Pannonian mass, which

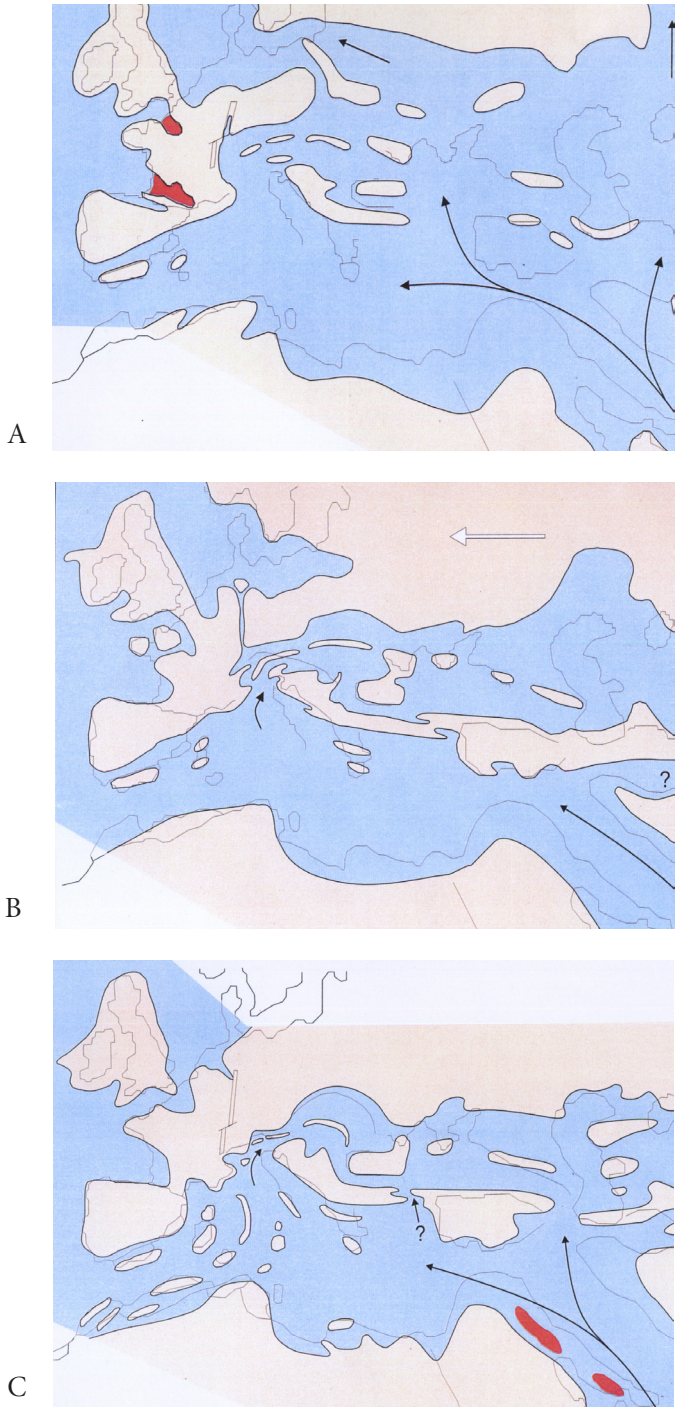


Fig. 1. Reconstruction of geotectonic processes and arrangements of certain segments of the Earth's crust in Southern Europe from the Late Eocene to Early Miocene (according to Rögl, 1998). A - Late Eocene, 37 - 33.7 M. B - Early Oligocene, 32 - 30 M. C - Early Miocene, 23.8 - 20.5 M.

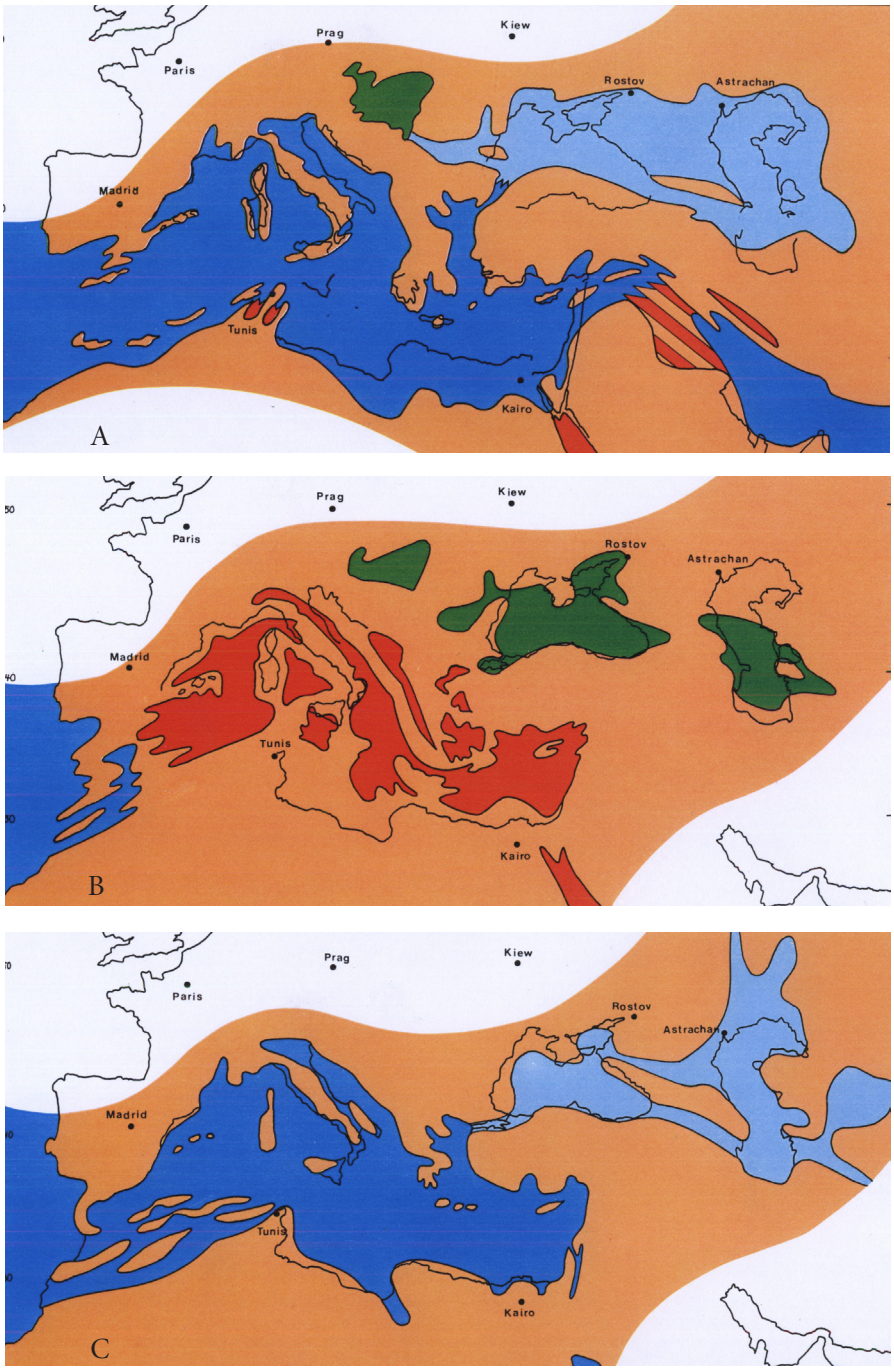


Fig. 2. Reconstruction of geotectonic processes and arrangements of certain segments of the Earth's crust in Southern Europe from the Upper Miocene to Pliocene (according to Rögl and Steininger, 1983). Dark blue - full marine facies; light blue - reduced marine facies; red - evaporite facies; orange - continental facies. A - Upper Miocene, 11.8 - 10.5 M. B - Upper Miocene, 6.0 - 5.5 M. C - Pliocene, 3.5 - 3.0 M.

is deeply subsided and covered with Neogene marine and lacustrine sediments. To the southeast, the link between the Rhodopian mass and the ancient block of Asia Minor is disrupted by sinking of the Aegean Sea (Laskarev, 1924; according to Ćurčić, 1998).

The tormented relief influences the climate of the Balkan Peninsula much more than does its geographical position in Southern Europe (Stanković, 1960). The Mediterranean climate is felt in the Greco-Aegean region and along the Adriatic Coast, as well as on the islands. The mountain ranges of the interior prevent further penetration of this climate. However, most of the Peninsula is largely open to the influence of the Central European climate, while the eastern part is under influence of the Pontic climate. The result is a series of climatic wheels, where different climatic influences prevail.

The Balkan Peninsula can be divided into several great natural regions characterized by geological and morphological features. The dominant fact is that the Alpine Orogeny here shows a classical bilateral structure: an orogenic branch stretches on each side of the intermediary crystalline mass – the Balkanic in the north and the Dinaric in the south.

BIOGEOGRAPHIC, BIOME, AND ECOSYSTEM DIVERSITY ON THE BALKAN PENINSULA

A historical-biogeographical analysis of the Balkan Peninsula showed that regions close in geomorphological and ecological respects usually differ biogeographically due to differences in the process of formation of their faunas. Particular attention has been paid to analysis of the biogeographical relations between contiguous and more remote biogeographical regions. A historical analysis of the main paths of formation of the contemporary biogeocoenoses in conformity with changes in ecological conditions since the Pliocene has also been carried out. The history of formation of the rich endemic fauna in the Balkan Peninsula, especially in the mountains, under the influence of mountain-forming processes, and the question of postdeluvial and prediluvial groupings in the mountains and their zonal distribution were discussed by Matvejev (1969).

Several attempts have been made to establish a biogeographical division of the territory of the Balkan Peninsula (Matvejev, 1961, 1969, 1973; Matvejev and Puncer, 1989). Accepting the contemporary arrangement of biomes into zonebiomes and orobiomes, Matvejev (1995, in: Lopatin and Matvejev, 1995) singled out nine floristic-faunistic ecosystem types at the level of zonebiomes and orobiomes on the territory of the Balkan Peninsula: 1. the zonebiome of Mediterranean maritime woodlands and maquis; 2. the zonebiome of Mediterranean semi-deserts; 3. the zonebiome of Ponto-Caspic steppes; 4. the zonebiome of sub-Mediterranean-Balkan forests; 5. the zone- and orobiome of Balkan-Central-European forests; 6. the orobiome of European forests of the taiga type; 7. the orobiome of European high-mountain rocks and tundra and wet high-mountain grasslands; 8. the orobiome

of Mediterranean mountain rocky woods; and 9. the orobiome of South Balkan mountain rocks and arid grasslands.

The biomes of the Balkans are distinguished by a large number (approximately 250 in total) of biotopes, i.e., roughly 35 biotopes in each biome. Diversity of the biotopes explains two particularities specific to the Balkan Peninsula – first, the greatest richness of flora and fauna in Europe; and second, an exceptional number of endemic and relict species. These facts imply that the present living world of Central Europe originates from the Balkan region, where sanctuaries (refugia) for the preglacial and glacial flora and fauna were located during the Glacial (Würm I-III). During the Postglacial, they populated the whole of Europe, becoming different at the same time (Matvejev, 1995, in: Lopatin and Matvejev, 1995).

The living world of the Tertiary on the Balkan Peninsula was similar to the living world of the present tropic and subtropic belt, while the uppermost vegetation was made up of the forests which correspond to the thermophilous variant of beech-fir forests of the recent vegetation (Lakušić and Dizdarević, 1983). During glaciation, there were no refugia in the continental Dinarids in which plants and animals that had lived in the Tertiary under a belt of mixed deciduous and coniferous forests of the *Abieti-Fagion sylvaticae* type could have survived. The diluvium was followed by a strong thawing process and humidity decrease, i.e., by a xerothermic period.

According to Horvat et al. (1974), the diversity of rich vegetation in Southeast Europe is illustrated by seven different vegetation zones and 31 sub-zones (Fig. 3). Central and Southern European vegetation is not distributed in clear tracts across the continent; instead, due to the existence of complex morphological and climatic patterns, a mosaic of various types is created. The Pannonian province is recent in origin and secondary in nature; it has a steppe-like appearance and covers the plains of the Middle Danube in the Carpathian basin. This latter belongs to a woodland belt having riparian oak forests mixed with Central European forests. The Continental province is the heartland of the West Palaearctic broad-leaved deciduous forest. The Central European Highlands include the Alps proper, as well as northern outliers. In this province, there is much Mediterranean influence and endemism (Stanners and Bourdeau, 1995). There are 154 centers of vegetal biodiversity on our planet, and six of them are found in Europe, including mountains of the Balkan Peninsula (WCMC, 1989).

FAUNAL DIVERSITY ON THE BALKAN PENINSULA

The Balkan Peninsula is a region where the influences of many biogeographical territories collide. Frequent changes in global ecological conditions throughout geological history have greatly contributed to the occurrence of an exceptionally heterogenous fauna. They have made this area a center of speciation for many groups of organisms. A number of endemic species are registered here as a result of this process.

Based on the basis of different criteria, several attempts have been made to date to establish a zoogeographical division of the Balkan Peninsula (Hadži, 1935; Matvejev, 1969, 1980; Guéorguiev, 1977; Josifov, 1981, according to Hubenov, 1997).

Matvejev (1980) gave a scheme (Fig. 4) of biogeographical division of the Balkan Peninsula for phanerobiontic living forms.

Not all parts of the Balkans are of equal zoogeographical importance in both the scientific and the conservation sense. On the basis of various studies and personal research, Vasić (1999) made an attempt to identify some of the most valuable areas within the Peninsula. The criteria used were of several very different kinds. Various zoo-geographical bridges have repeatedly connected and detached the Balkan mainland with European, African, and Asian lands during its history. The relic taxa documenting faunistic exchanges between adjacent and even remote regions often indicate the existence of paleo-geographical dynamism in particular areas of the Balkan Peninsula. The various zones are usually inhabited by a unique and difficult to understand mixture of animal diversity. Zoo-geographical dynamism, caused partly by intrinsic and partly by extrinsic factors (including ones affected by man) show regularities in a way that reveals the particular corridors of expansions within the Balkan Peninsula.

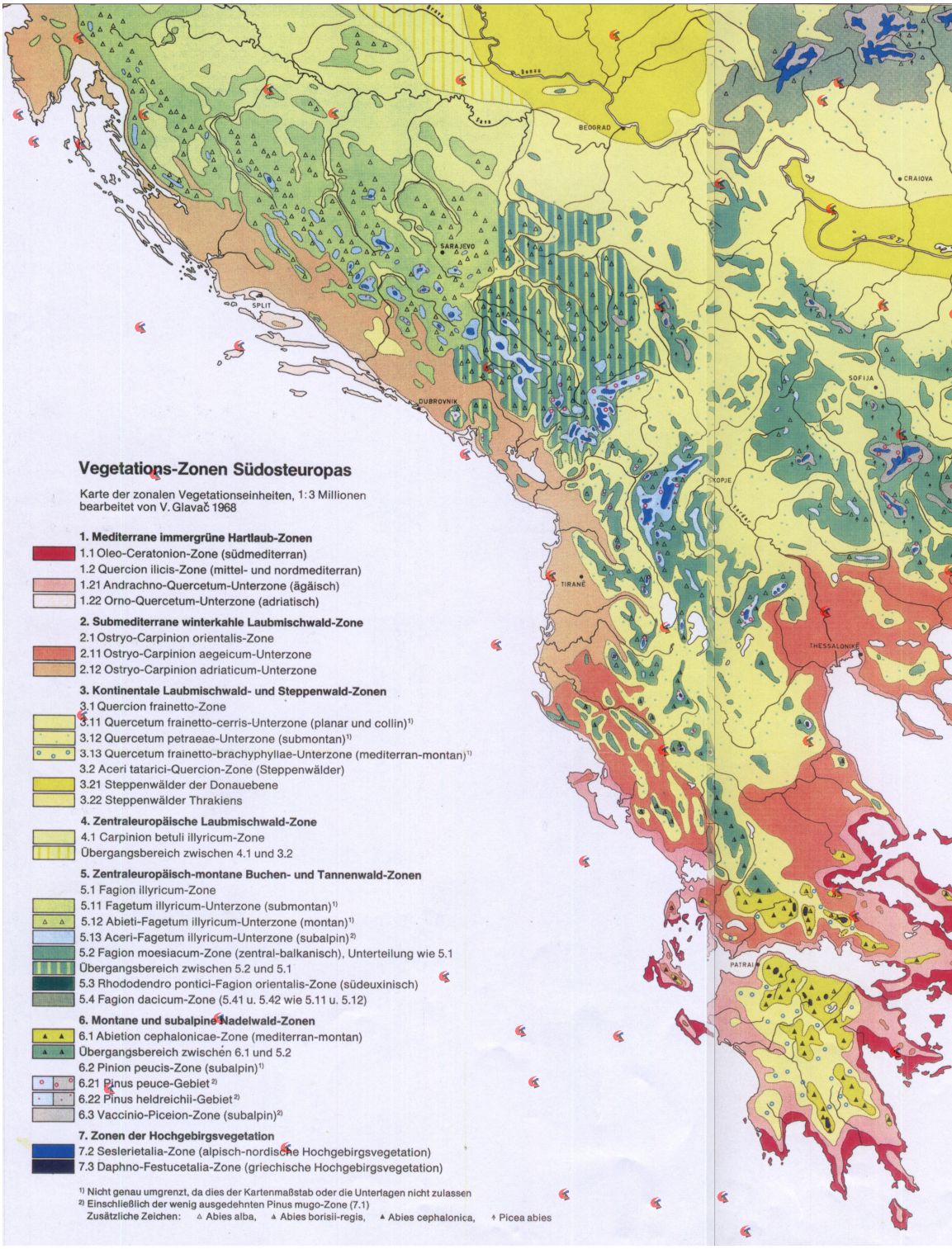
Separate studies on taxonomic diversity of specific taxons exist for the general region of the Balkan Peninsula.

Thus, the Balkan Peninsula constitutes a vast refugial zone for both paleo- and neoendemic forms. Additionally, this area represents the site of an evolutionary "explosion" (or adaptive radiation) of species in many invertebrate groups. Although the reasons for such variety and abundance are not sufficiently clear, it is assumed that the diversity of once existing fauna, suitable climatic conditions, and geotectonic and geomorphological events played an outstanding role both in species diversification and in sheltering (Ćurčić and Lučić, 1997; Ćurčić, 1998).

It would be particularly interesting to perform a comparative analysis of the zoogeography and taxonomical diversity of contrasting life forms with different dispersal ability - life forms with diminished mobility such as subterranean and cave-dwelling representatives on the one hand, and highly mobile life forms such as birds on the other.

The origin of the rich endemic and relict troglobitic fauna in Serbia and Montenegro has been largely affected by the exceptionally great heterogeneity of the ancient epigean fauna populating the Proto-Balkans in the remote past; by continuity of the continental phase in different areas of the Balkans, which has been maintained since the Paleozoic Era; by the presence of deep limestone sediments; by intensive karstification and subsequent development of the underground karst relief; by a succession of suitable climatic conditions, which made possible the survival of both endangered and vanishing species; and by the adaptive radiation of species in newly emerged habitats (Ćurčić et al., 1998). The territory of Serbia and Montenegro must therefore be considered an important center of endemic differentiation of species, not only on the Balkan Peninsula, but also in the whole eastern part of the Mediterranean region.

Biospeleological zonation of the Balkan Peninsula, as defined by Guéorguiev (1977), has contributed greatly to the study of its zoogeography. The Tertiary


BEOGRAD
CRAIOVA
SARAJEVO
SPLIT
DUBROVNIK
SOFIJA
SKOPJE
TIRANE
THESSALONIKE
PATRAI
Vegetations-Zonen Südosteuropas
Karte der zonalen Vegetationseinheiten, 1:3 Millionen
bearbeitet von V. Glavač 1968
1. Mediterrane immergrüne Hartlaub-Zonen
1.1 Oleo-Ceratonion-Zone (südmediterran)
1.2 Quercion ilicis-Zone (mittel- und nordmediterran)
1.21 Andrachno-Quercetum-Unterzone (ägäisch)
1.22 Orno-Quercetum-Unterzone (adriatisch)
2. Submediterrane winterkahle Laubmischwald-Zone
2.1 Ostryo-Carpinion orientalis-Zone
2.11 Ostryo-Carpinion aegeicum-Unterzone
2.12 Ostryo-Carpinion adriaticum-Unterzone
3. Kontinentale Laubmischwald- und Steppenwald-Zonen
3.1 Quercion frainetto-Zone
3.11 Quercetum frainetto-cerris-Unterzone (planar und collin)1)
3.12 Quercetum petraeae-Unterzone (submontan)1)
3.13 Quercetum frainetto-brachyphyllae-Unterzone (mediterran-montan)1)
3.2 Aceri tatarici-Quercion-Zone (Steppenwälder)
3.21 Steppenwälder der Donauebene
3.22 Steppenwälder Thrakiens
4. Zentraleuropäische Laubmischwald-Zone
4.1 Carpinion betuli illyricum-Zone
Übergangsbereich zwischen 4.1 und 3.2
5. Zentraleuropäisch-montane Buchen- und Tannenwald-Zonen
5.1 Fagion illyricum-Zone
5.11 Fagetum illyricum-Unterzone (submontan)1)
5.12 Abieti-Fagetum illyricum-Unterzone (montan)1)
5.13 Aceri-Fagetum illyricum-Unterzone (subalpin)2)
5.2 Fagion moesiacum-Zone (zentral-balkanisch), Unterteilung wie 5.1
Übergangsbereich zwischen 5.2 und 5.1
5.3 Rhododendro pontici-Fagion orientalis-Zone (südeuxinisch)
5.4 Fagion dacicum-Zone (5.41 u. 5.42 wie 5.11 u. 5.12)
6. Montane und subalpine Nadelwald-Zonen
6.1 Abietion cephalonicae-Zone (mediterran-montan)
Übergangsbereich zwischen 6.1 und 5.2
6.2 Pinion peucis-Zone (subalpin)1)
6.21 Pinus peuce-Gebiet2)
6.22 Pinus heldreichii-Gebiet2)
6.3 Vaccinio-Piceion-Zone (subalpin)2)
7. Zonen der Hochgebirgsvegetation
7.2 Seslerietalia-Zone (alpisch-nordische Hochgebirgsvegetation)
7.3 Daphno-Festucetalia-Zone (griechische Hochgebirgsvegetation)
1) Nicht genau umgrenzt, da dies der Kartenmaßstab oder die Unterlagen nicht zulassen
2) Einschließlich der wenig ausgedehnten Pinus mugo-Zone (7.1)
Zusätzliche Zeichen: Abies alba, Abies borisii-regis, Abies cephalonica, Picea abies

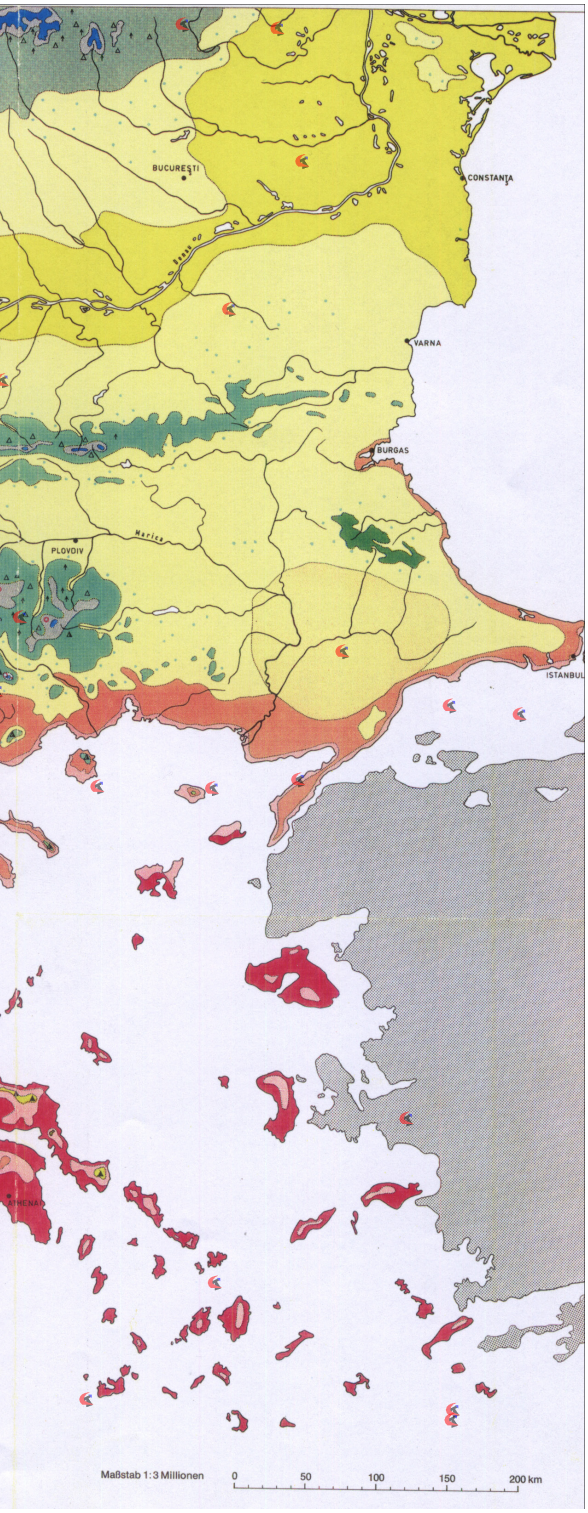


Fig. 3. Vegetation zones of Southeast Europe

Map of the zonal vegetation units, 1 : 3 millions modified by V. Glavač (Horvat et al., 1974)

1. Mediterranean evergreen sclerophyll zones
1.1 Oleo-Ceratonion zone (South Mediterranean)
1.2 Quercion ilicis zone (Middle and North Mediterranean)
1.21 Andrachno-Quercetum sub-zone (Aegean)
1.22 Orno-Quercetum sub-zone (Adriatic)
2. sub-Mediterranean deciduous summer mixed forest-zone
2.1 Ostryo-Carpinion orientalis zone
2.11 Ostryo-Carpinion aegeicum sub-zone
2.12 Ostryo-Carpinion adriaticum sub-zone
3. Continental mixed broad-leaved forest and woodland steppe zones
3.1 Quercion frainetto zone
3.11 Quercetum frainetto-cerris sub-zone (plain and hill)[1)]
3.12 Quercetum petraeae sub-zone (sub-mountainous)[1)]
3.13 Quercetum frainetto-brachyphyllae sub-zone (Mediterranean-mountainous)[1)]
3.2 Aceri tatarici-Quercion-zone (wooded steppe)
3.21 Wooded steppe of the Danube plain
3.22 Wooded steppe of Thrace
4. Central European mixed broad-leaved forest zone
4.1 Carpinion betuli illyricum zone
Transitional region between 4.1 and 3.2
5. Central European mountainous beech and fir forest zones
5.1 Fagion illyricum zone
5.11 Fagetum illyricum sub-zone (sub-mountainous)[1)]
5.12 Abieti-Fagetum illyricum sub-zone (mountainous)[1)]
5.13 Aceri-Fagetum illyricum sub-zone (subalpine)[2)]
5.2 Fagion moesiacum zone (Central Balkan), subdivision into districts as 5.1; Transitional region between 5.2 and 5.1
5.3 Rhododendro pontici-Fagion orientalis zone (South-Euxinian)
5.4 Fagion dacicum zone (5.41 and 5.42 as 5.11 and 5.12)
6. Mountainous and sub-alpine conifer forest zones
6.1 Abietion cephalonicae zone (Mediterranean mountainous)
Transitional region between 6.1 and 5.2
6.2 Pinion peucis zone (sub-alpine)[1)]
6.21 Pinus peuce region[2)]
6.22 Pinus heldreichii region[2)]
6.3 Vaccinio-Piceion zone (sub-alpine)[2)]
7. Zones of high-mountain vegetation
7.2 Seslerietalia zone (alpine-arctic high-mountain vegetation)
7.3 Daphno-Festucetalia zone (Greek high-mountain vegetation)

[1)]Not precisely delimited, because of the map scale or substratum limitations.
[2)]Including the poorly distributed Pinus mugo zone (7.1)
Additional symbols: Abies alba, Abies borisii-regis, Abies cephalonica, Picea abies

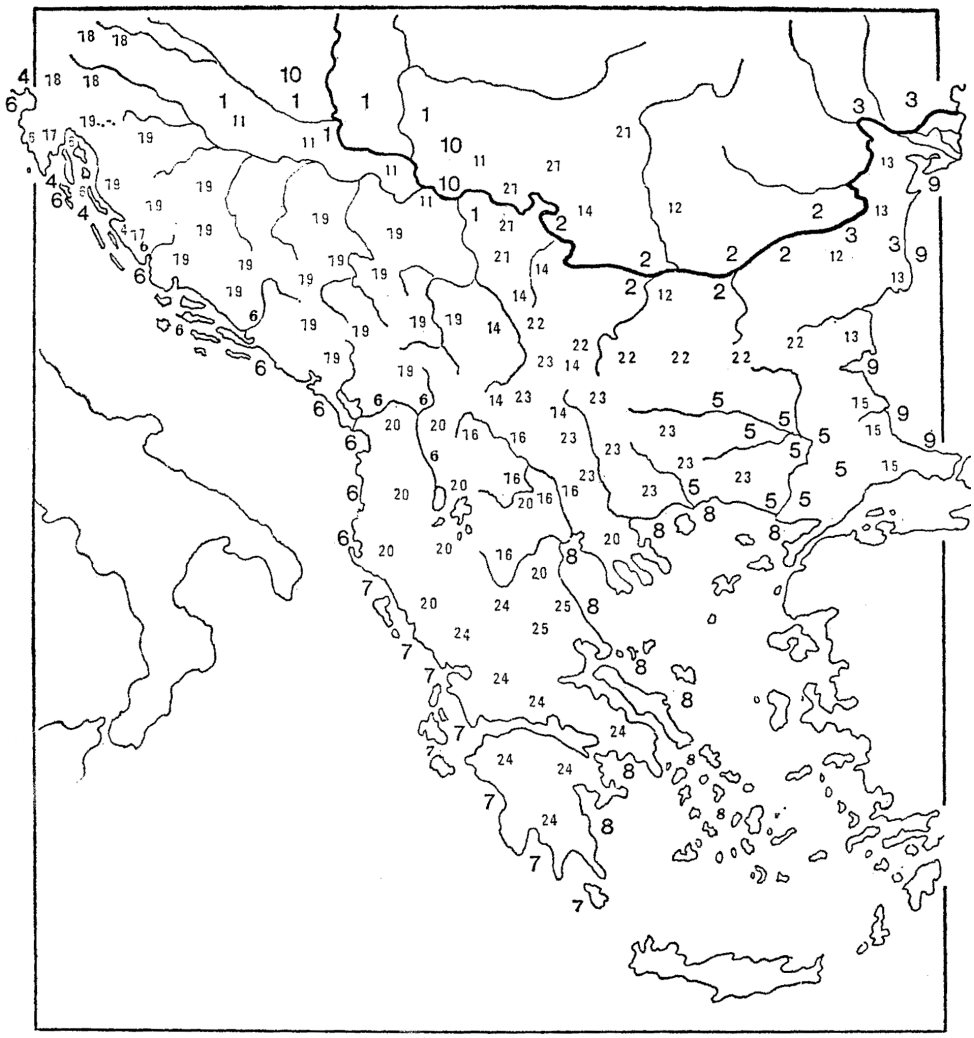


Fig. 4. Scheme of biogeographical and faunistic territories of the Balkan Peninsula and adjacent countries. Distribution of faunistic elements. A. Plains: 1. Pannonian; 2. Dacian (Vallachian); 3. Pontian; 4. Lombardian; 5. Thracian; 25. Thessalian. B. Coasts of the following Mediterranean seas: 6. Adriatic; 7. Ionian; 8. Aegean; 9. Pontian; 10. Ancient Pannonian. C. Characteristic hill and sub-montane elements: 11. sub-Pannonian; 12. sub-Dacian; 13. sub-Pontian; 14. Moesian; 15. Strandjanian; l6. Macedonian; 17. Liburnian. D. Elements characteristic of mountain systems: 18. Eastern Alps; 19 Northern Dinarids; 20. Southern Dinarids; 21. Carpathian; 22. Balkan Range (Stara Planina); 23. Rilo-Rhodopes; 24. Mountains of Southern Greece and Peloponese; 25. Thessalian plain (Matvejev, 1980).

orogeography in the western part of the Peninsula has been reconstructed on the basis of the main biogeographical barriers for recent troglobites. The existence of ancient tectonic faults, assumed on the basis of distribution of the troglobitic fauna, caused division of the Balkan Peninsula into two biospeleological realms, four provinces, 11 zones, and over 45 areas. Analysis of paleogeography of the Balkans

has clearly demonstrated the outstanding richness of the Mediterranean cave fauna in the area studied.

According to the last check list of world Lumbricidae (after Easton, 1983), the total number of registered species and subspecies amounted to 386. Since 1983, this number has increased to about 450 species and subspecies. Mršić (1991) listed 231 species and subspecies registered for the territory of the Balkans and neighboring countries (167 of them being registered as the fauna of former Yugoslavia), which represents one half of the earthworm fauna as a whole. The abundance of earthworms on the Balkan Peninsula is conditioned by the diversity of its climatic and edaphic factors (overlapping of various zoogeographic regions), as well as by great orogenic changes in the past. This is why the Balkans are an important center of earthworm development.

Šapkarev (1997) found a high degree of endemicity of the lumbricid fauna in the Balkans. Altogether, 153 endemic taxa (130 species and 23 subspecies) have been identified in the Balkans up to now. On the basis of their distribution, all endemic taxa are divided into three groups: endemites with very restricted area; endemites more widely distributed in the Balkans; and endemites also occuring in some neighboring Balkan countries.

Teerrestrial Isopoda of the Peninsula are characterized by a remarkably high percentage of endemic species not recorded in any other region of the Northern Hemisphere. Of 445 terrestrial isopods recorded so far, 345 are endemic to certain parts of the Northern Mediterranean area and 36 are Balkan endemics. Taken as a whole, 381 species (or 85.6%) are endemic to the Balkan Peninsula. In addition to the species level, the endemism of terrestrial isopods of the Balkan Peninsula is also highly expressed at the generic level (of a total of 76 genera, 36 are endemic to the area) (Andreev, 1997).

The territories of Serbia, Montenegro, and the Republic of Macedonia are home to 119 pseudoscorpion species, belonging to 15 genera and six families (Ćurčić et al., 2004). The number of species is comparatively high in relation to the number of species recorded from other countries of the Balkan Peninsula. On the basis of their current distribution, the established 119 species can be relegated to 13 zoogeographical categories, grouped into four complexes (cosmopolitan, widely distributed, European, and endemics). The largest number of species belong to the endemic complex, and the most characteristic species are in this group. The number of endemic species established (87) is comparatively high and reflects the local character of the fauna. This phenomenon can be regarded as a result of relative isolation of the mountains on the Balkan Peninsula compared to the lowlands within the context of paleo-environmental changes during the Tertiary.

The territory of Serbia is home to 618 spider species, belonging to 221 genera and 36 families. The number of species is relatively high in comparison with the number recorded from other countries of the Balkan Peninsula. High numbers of species are recorded for the territories of Bulgaria (910), Greece (810), and Croatia (615). On the basis of their current distribution, the established 618 species can be relegated to

25 zoogeographical categories, grouped into five complexes (cosmopolitan, widely distributed, European, endemics, and Mediterranean). The largest number of species belong to the widely distributed complex, but the most characteristic species are the endemics. The number of endemic species established (21) is comparatively high and reflects the local character of the fauna. As in the case of pseudoscorpions, this phenomenon can be regarded as a result of relative isolation of the mountains on the Balkan Peninsula compared to the lowlands within the context of paleo-environmental changes during the Tertiary (Deltshev et al., 2003).

According to Deltshev (2004), faunistic diversity of the 1409 spider species shows that the Balkan Peninsula is a territory with considerable species richness. This conclusion is also supported by the existence of 379 endemic species. In terms of zoogeography, widely distributed spiders are dominant, but the most characteristic faunal elements are the Balkan endemics. Their number is high, and their faunistic composition reflects the local character of the fauna. Again it should be stressed that this phenomenon is attributable to relative isolation of the mountains compared to the lowlands within the context of paleoenvironmental changes since the Pliocene. The high percentage of Balkan endemics (26.9%) suggests an important process of speciation *in situ*. Thus, the existing data suggest that the Balkan Peninsula represents one of the main centers of speciation in Europe.

The fauna of diplopods of Serbia, Montenegro, and the Republic of Macedonia is represented by a total of 145 species belonging to 51 genera and 21 families (Makarov et al., 2004). Of 145 species inhabiting the areas studied, 41 (or 28.275%) are endemic in these regions; of 51 genera, only six (or 11.76%) are endemic to the same areas. Eighty diplopod species have been found in Serbia, 69 in Montenegro, and 61 in the Republic of Macedonia. Of the total number of millipede species, 16, 12, and 12 are endemic to Serbia, Montenegro, and the Republic of Macedonia, respectively. The most abundant are the families Julidae (54 species or 37.20%) and Polydesmidae (36 species or 24.83%). Based on their current distribution, the established 145 species can be relegated to 10 zoogeographical categories, grouped into four complexes (endemics, Central-East-Southeast European, European, and widely distributed). The largest number of species belong to the endemic complex, which includes 93 species (or 64.14%).

The fauna of springtails in former Yugoslavia (i.e., Serbia and Montenegro) is very rich and diverse; altogether, 233 species are known from Serbia (Bogojević, 1968, according to Ćurčić and Lučić, 1997). These are classified into 43 genera and five families. In Montenegro, 89 species have been recorded; these belong to 10 genera and seven families. Of the total number of species, 28 species and subspecies are endemic to Serbia (12.02%) and 11 (12.36%) to Montenegro. The majority of endemic and relict forms inhabit caves and potholes, but some of them populate forests and cultivated areas. Two centers of endemic differentiation of springtails are presently recognized in former Yugoslavia: (a) in its northern and eastern part (Eastern Serbia); and (b) in its southern and western part (Montenegro, Western and Southwest Serbia) (Ćurčić and Lučić, 1997).

Springtails seem to have been sensitive to the devastating effect of the Ice Age. This accounts for the present depauperate Yugoslav fauna at higher altitudes and its modern distribution pattern. On the other hand, certain genera have retained quite a sizable number of paleoendemic taxa. Therefore, the former Yugoslavia (i.e., Serbia and Montenegro) should be regarded as an important center both of divergent differentiation of species and of colonization towards the eastern parts of the Balkan Peninsula and elsewhere (Ćurčić and Lučić, 1997).

Zoogeographic analysis of the Heteroptera of Balkan Peninsula reveals characteristics of the distribution of this group in the latitudinal, longitudinal, and vertical directions. The results of these studies indicate division of the Balkan Peninsula into four zones of Mediterranean, Euro-Siberian, and Palearctic species complexes (1. Euro-Siberian zone; 2. sub-Euro-Siberian zone; 3. sub-Mediterranean zone; and 4. Mediterranean zone), which due to orographic features exhibit a mosaic character (Josifov, 1981, according to Hubenov, 1997).

The zoogeography of Heteroptera inhabiting Southern Europe shows a varied distribution of Mediterranean species in the broadest sense. Their range encompasses the southern parts of the Euro-Siberian subregion. In the Mediterranean subregion, these species are separated from Euro-Siberian ones by vertical disjunctions, namely mountains, whereas in Central and Northern Europe these disjunctions are reduced, with the result that the mentioned species are sympatric. Species with Euro-Siberian and Palearctic distribution are closely related, both in the narrow and broader sense.

Migrating southward during the Miocene and Pliocene, the thermophilic Heteroptera expanded as a forerunner of the recent Mediterranean fauna. On the basis of endemic genera, two principal primordial areas of their genesis (Tyrrhenian and Aegean) in the region of the northern Mediterranean area have been defined. A frigophilic/psychrophilic fauna, represented by Palearctic and Euro-Siberian species, penetrated the Balkan Peninsula during the Quaternary. Additionally, postglacial disjunctions in the distribution of some Euro-Siberian species during the Holocene resulted in the occurrence of endemism at the species level (Josifov, 1976, 1981, 1990; according to Hubenov, 1997).

The fauna of ground beetles in Serbia is very diverse and rich in taxa. Of 576 species inhabiting the area studied, 21 (or 3.65%) are endemic in this region, while of 167 registered subspecies, 27 (or 16.17%) are endemic to the area. Of the total number of ground beetle genera (107), four (or 3.74%) are endemic to Serbia. The total number of subfamilies in the region studied is 10, and that of tribes is 32. The most abundant are the tribes Harpalini (102 species or 17.71%), Bembidiini (85 species or 14.76%), Pterostichini (69 species or 11.98%), and Zabrini (50 species or 8.68%). On the basis of their current distribution, the established 576 species can be relegated to 13 zoogeographical categories, grouped into five complexes (endemics, Mediterranean, European, widely distributed, and cosmopolitan). The largest number of species belong to the chorological complex of widely distributed forms (312 species or 54.17%). The endemic complex includes 85 species (or 14.76%) (S. B. Ćurčić et al., 2007).

The weevil fauna of high-altitude habitats on the mountains of the central Balkan Peninsula is characterized by a high level of taxonomic diversity (Mesarosh, 1996). Almost 50 of 80 endemic weevil species from former Yugoslavia (Serbia and Montenegro) inhabit high altitudes. The evolutionary divergence of these taxa is a result of complex interactions between internal and external factors. In the case of high-altitude weevils, it was demonstrated that the main internal factor for evolutionary divergence is the specific population structure of these taxa.

Long-term investigations on syrphids (Šimić et al., 1999) has resulted in recognition of about 500 species on the Balkan Peninsula. Generally, two groups of endemics can be distinguished: endemics with relatively wide distribution, and local endemics and relicts. The first group includes European endemics of several categories (Central European, Alpine and high-mountain, Mediterranean, etc.) and Balkan-Caucasian endemics of several categories (Balkan-Carpathian-Caucasian, Carpathian, Pannonian-Pontic, Pannonian-Dacian, etc.). The numerous local Balkan endemics and relicts are also grouped in appropriate categories.

According to Jakšić (1998), the fauna of diurnal Lepidoptera of the Balkan Peninsula is represented by 288 species.

Balkan amphibians and reptiles are diverse in many respects. Species richness is very high, with a total of 104 species (33 amphibians and 71 reptiles), two of which are introduced (Džukić and Kalezić, 2004). It is likely that a number of morphologically cryptic taxa also exist. The highest level of species diversity is recorded in the region of the "Adriatic Triangle" (the Prokletije Mountain Massif and adjacent areas), while the peri-Pannonian area and Dobruja are the most species-poor regions. The Balkans are a center of endemicity in Europe, with *ca.* 28% of amphibians and 21% of reptiles being endemic. In addition, more than half of the rest of autochthonous species have the marginal zone of their range in the Balkans, with marked differences between amphibians and reptiles in regard to the orientation of dominant range borders.

The Balkan batrachofauna and herpetofauna have varied biogeographical origins and connections with other regions. The Balkans appear to have been a center of intense speciation within some taxonomic groups. Also, there have been a significant number of migrations of amphibians and reptiles from other zoogeographical areas. Central and Northern Europe appear to have been repeatedly populated by expansions from Balkan refugia during Pleistocene interglacials. Certain groups have withdrawn from Northern and Central European latitudes, some of them being restricted to southern refuge areas. The zoogeographical map of the Balkan Peninsula is very complex, with elaborate subdivisions and numerous discontinuities, as well as a wealth of preglacial faunal elements (Džukić and Kalezić, 2004).

The diversification and geographical distribution of birds, i.e., animals with extremely high mobility, on the Balkan Peninsula were discussed by Vasić (1994). His analysis of avian diversity on the Balkan Peninsula was based mainly on previous studies of zoogeographical borders or contact zones, as well as on the comparatively well-known avifaunal composition of large parts of the area. The Balkan Peninsula appears to be a well-defined biogeographical unit, with the highest avian diversity

in its central parts. The considerable increase of diversity at its edges is an effect typical of transitional zones, i.e., biogeographical borders.

The Balkan avifauna is one of the two richest in Europe. The other is the Iberian one. The number of bird species breeding in Balkan countries varies around an approximate figure of 300 (according to different authors). Considering avian diversity as diversity of species or, more precisely, as richness of the total number of species, Vasić (1994) calculated the species density for the whole territory of the Balkan Peninsula and compared it with that of the adjacent Italian Peninsula with its islands. With an approximate total number of 300 bird species on the Balkan area of 486,000 km^2, the species density index is 22.93. In Italy, the presence of 256 species (according to Brichetti, 1978) on an area of 301,278 km^2 gives a species density index of 20.30.

Much more important than an average expression, at least from a conservationist point of view, is the geographical distribution of biodiversity on the Balkan Peninsula, which allows the establishment of international or sub-regional conservation strategies and protection priorities. For these purposes Vasić (1994) divided the entire Balkan Peninsula into 24 territories, i.e., zoogeographical provinces, using various complex criteria, and presented the relation between topography and avian diversity in three-dimensional graphs. The main principle was the biomic one. Each province has its characteristic complex of biomes or landscape types in the sense suggested by Matvejev and Puncer (1989, 1991).

Studies of the history and origin of recent mammals confirms the existence of parallelism between the main stages of their evolution and corresponding climatic changes. In formation of the recent mammal fauna of the Balkans, the cold and dry climates prevailing during the Oligocene were of particular importance. The study of fossil and recent communities of small mammals on the territory of central and northern and western parts of the Balkan Peninsula led to the conclusion that the time from the end of the Pliocene to the present day has seen significant differentiations in the spreading of biogeographical zones (Markovic and Pavlovic-Angos, 1994).

According to Storch (2004), the Balkans are usually considered to have been an important refuge for European mammalian faunas during Pleistocene glacial episodes. The northern Balkan regions may well have contributed to the re-establishment of present-day Central European temperate rodent faunas after arctic and continental Asian associations vanished during the dramatic faunal turnover of the Late Glacial and the Pleistocene-Holocene boundary about 10,000 y.B.C. In neighboring areas to the south, however, most of the Balkan region mirrors rather continuous autochthonous evolutionary processes during the Late Quaternary, occasionally resulting in taxa indigenous to these areas only.

Savić et al. (1995) described patterns in mammal richness and assessed mammalian diversity on the territory of former Yugoslavia (Serbia and Montenegro). Figure 5 presents a very illustrative picture of the process of diversification and geographical distribution of fossil and recent subterranean mammals with restricted

mobility, as well as animal bioindicators of certain types of plant communities, on the Balkan Peninsula (Savić and Soldatović, 1984; Savić and Nevo, 1990).

Between 35 and 60 species of insectivores, bats, rodents, and mustelids were found to occur in individual 100 x 100 km squares superimposed on the Balkan Peninsula (Kryštufek, 2004). Hot spots of species richness coincided with the southern Dinarids, the Šar-Pindhos Mountains, the Rila-Rhodopes, and the Balkan Mountains. Area-adjusted species richness of the Balkan Peninsula was significantly higher than for the rest of Europe, although Balkan mammal diversity was significantly lower than that of the Near and Middle East. Hot spots of endemism in the southern Dinarids and northern Šar-Pindos Mountains coincided with those of species richness. K-mean clustering on a species presence/absence matrix revealed two main clusters: a northern and a southern one.

Studies of faunal diversity in specific regions of the Balkan Peninsula (for example Bulgaria, former Yugoslavia, Greece, the Danube River) also exist.

Although Bulgaria is relatively small in size (110, 912 km^2), it is rich in biological diversity due to its highly varied climatic, geological, topographic, and hydrological conditions. According to the Biodiversity Support Program (1994), these conditions allow Bulgaria to support a biota that includes 94 species of mammals, 383 birds, 36 reptiles, 16 amphibians, 207 Black Sea and freshwater fish, an estimated 27,000 insects and other invertebrate species, between 3,550 and 3,750 species of vascular plants, and more than 6,500 nonvascular plants and fungi. Thus, Bulgaria ranks among the most biologically diverse countries in Europe. Also, Bulgaria's biota includes a significant number of endemic species and subspecies. Bulgaria is characterized by a wide variety of plant and animal communities, and supports examples of almost all of the main habitat types found in Europe.

According to Stevanović et al. (1996), recent analysis and close inspection of the flora and fauna distributed in former Yugoslavia (Serbia and Montenegro) show that they are among the richest in Europe. The abundance and diversity of taxa, ecosystems and landscapes can be explained attributed to various climatic, geomorphological, petrographic, orographic, and hydrographic features, as well as to a great number of refugial habitats throughout the territory, where a significant number of relict and endemo-relict species and communities (dating back as far as the Tertiary and Ice Age) have been preserved. The territory of Yugoslavia was one of the most significant refugial regions of Europe during the Ice Age. From the biogeographical point of view, almost all basic chorions of Europe are present within the territory of Yugoslavia. On the territory of Yugoslavia, seven landscape types (biomes) were singled out by Matvejev and Puncer (1989). In comparison, there are three landscape types in Northern Europe and four in Central Europe. Certain smaller geographical areas bear an extremely high biological diversity of particular groups of animals. Over 51 species or even 57 subspecies (including many endemic ones) of reptiles and amphibians, for example, live in the relatively small area of Southeast Montenegro. Such a concentration of species is the highest in Europe.

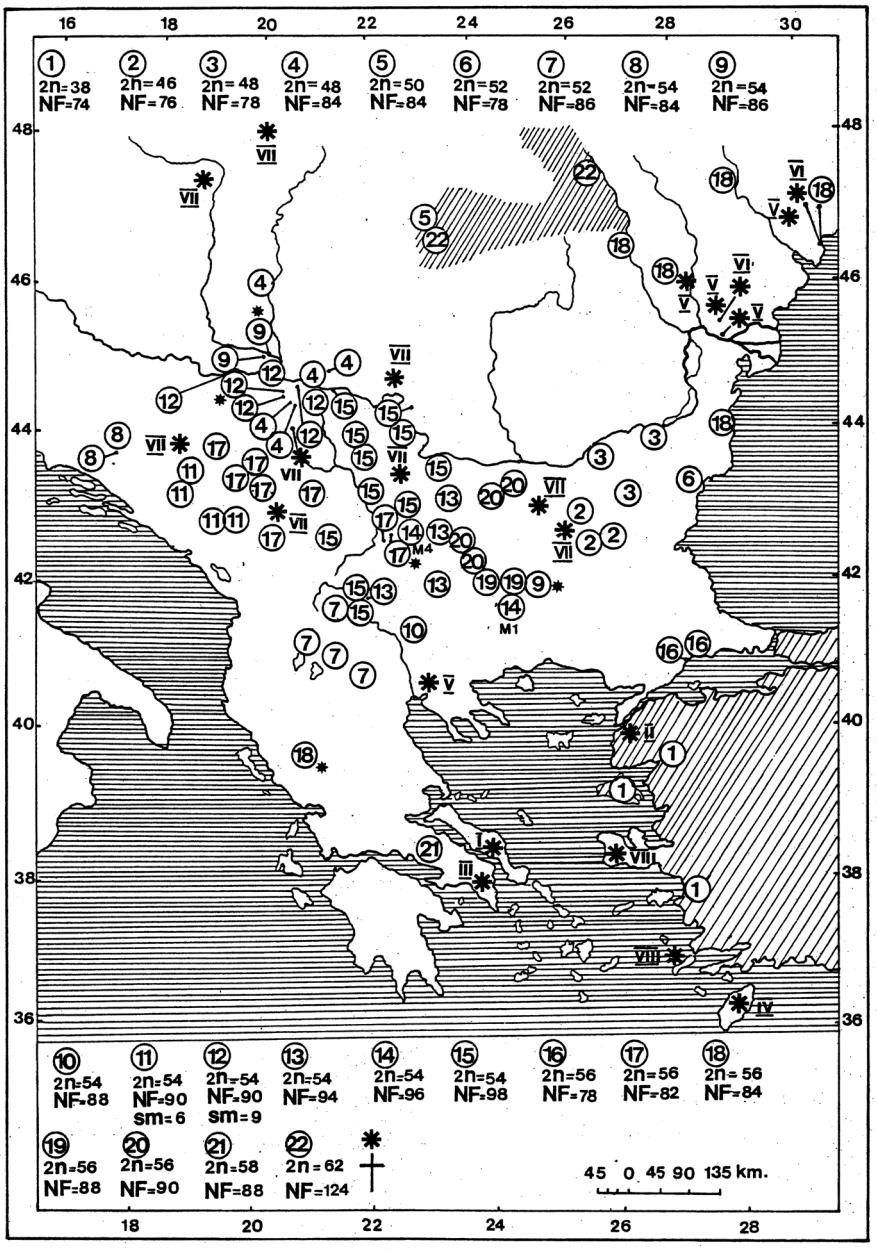


Fig. 4. Fossil findings (asterisk) and karyotype forms (circles) of mole rats (Spalacinae) in Southeast Europe and the western part of Asia Minor. Fossil findings: I - *Heramys eviensis* (Lower Aragonian); II - *Pliospalax canakkalensis* (Late Aragonian); III - *P. tourkobouniensis* (Lower Pleistocene); IV - *P. sotirisi* (Upper Pliocene); V - *P. macoveii* (Middle Pliocene - first half); VI - *Microspalax odessanus* (Late Ruscinian); VII - *Spalax cf. leucodon* (Upper Pleistocene); VIII - *S.* cf. *nehringi* (Middle Pleistocene); thick slanted shading - area of the species *S. graecus* (22); thin slanted shading - area of the species *S. nehringi* (1); M - No. of metacentrics; sm - No. of sub-metacentrics; small asterisks - some aberrant karyotypes (Savić and Nevo, 1990, according to Savić and Soldatović, 1984, and Peshev and Vorontsov, 1982).

Greece is a country with rich biodiversity and a wide variety of ecosystems in good condition compared to the rest of Europe. Its flora and fauna are among the richest in Europe. The variety of vegetation, flora and fauna is reflected in the equally sizable variety of ecosystems. In Greece, the following vertebrates have been recorded: 520 species of marine fish (41.6% of the European marine fish fauna); 79 freshwater fish species (15.8% of European species, including 39 or 49.4% endemic species); 16 amphibians (27.6% of European species, including two endemic species); 58 reptile species (41.4% of European species, including seven endemic species); 407 bird species (90.4% of European species); and 116 mammals (61.6% of European species, including two endemic species). One remarkable feature of this diversity is that the number of bird species recorded in Greece reaches an amazing 90% of the European total (Hellenic Ornithological Society, 1994). Another important feature is the high endemism of Greek freshwater fish: 49.4% of the total of Greek species.

Study of the biota of old lakes, whose present composition is the result of a long and complicated history, enables us to evaluate importance of the influence of long geographical isolation on the development of lake biotas. Indeed, these old lakes were occupied at the beginning of their existence by elements of the Tertiary aquatic world, whose composition – to judge from numerous fossil remains - was very different from that of the recent world. Such lakes include the large and old Lake Ohrid, whose very existence was almost unknown two centuries ago. An extraordinary wealth of endemic organisms exists there, surpassing that of any other European lake, which leads us to consider it as unique in Europe, comparable only with Lake Baikal and the Caspian Sea in the whole Palearctic region (Stanković, 1960).

The river network of the Balkan Peninsula includes rivers flowing in all directions, each having its own faunistic peculiarities and endemics. According to Banarescu (2004), seven regions corresponding to groups of river drainages are present on the Peninsula, together with the lakes of Ohrid and Prespa, which are dealt with separately. The fish fauna of the Danube Basin is very uniform (Janković and Jovičić, 1994; Banarescu, 2004), although the hydrobioid snail fauna of the southwestern tributaries is quite distinct from that of the remaining part of the basin, being closely related to that of the western Balkan watershed. The degree of endemicity is very high, especially in Lake Ohrid and the rivers of Dalmatia (the western watershed). Most fish and representatives of aquatic groups are classed as continental. It is not clear whether the hydrobioid snails, the aquatic group with the highest number of species, should be considered as of continental or marine origin. Many aquatic animals of the Peninsula are long-established, but there are some recent intruders, even in Lake Ohrid.

CONCLUDING REMARKS

The history of the lithosphere of the Balkan Peninsula is unique and in many ways it is different from the history of other parts of the lithosphere, especially those of Northern Europe. Its main characteristic is that it belongs to the youngest regions of Europe (Neo-Europe), which were gathered into one entity only a few tens of

millions of years ago and which had long been scattered over a much wider area before they were put together and added to the older parts of Europe. This means that Europe passed through several periods of enlargement. Such a specific history of all relevant natural systems in geological time has left a very rich geo-heritage on Balkan territory. It can be safely said that the Balkan Peninsula is unique in the world as a treasure trove of geo-heritage.

With respect to the Balkan Peninsula, we must emphasize that it is characterized by an exceptionally rich and diversified fauna. As regards biodiversity, the Balkan Peninsula is among the most significant regions in Europe and the world. There are a great number of plant and animal species, many of which are of an endemic or relict character, which is a consequence of the specific history of this region (among other factors), especially during the Ice Age.

Vegetation and ecosystem biodiversity here is almost unbelievably rich and varied, as can be concluded from the fact that in the Alpine and high-Nordic region above the upper forest boundary in mountains of the Balkans, there are vegetation and ecosystems which are very similar to those which can be found in the Far North, in polar and subpolar regions. In northern parts of the Mediterranean Sea, especially those surrounding the Balkan Peninsula (the Adriatic, Ionian, and Aegean Seas) we find high biodiversity of creatures characteristic of the living world of seas and oceans. In addition to taxonomic biodiversity of animal species on the Balkan Peninsula, there is also great diversity in regard to cenotic organization of the living world (phytocenoses, biocenoses, ecosystems, regions), as expressed in the diversity of forests, meadows, sand ecosystems, water and swamp biocenoses, high-mountain areas, etc.

Many Balkan species are endemics and can be found nowhere else on the planet. The reasons for this great diversity and endemism on the Peninsula are thought to be: its geographical position between Europe, Asia, and Africa; the geological history of the area studied; its diverse geomorphology (many mountains and islands); and its consequently diverse climate - all of which result in a vast variety of biotopes.

There are important differences of opinion about the endangerment of particular groups of animals and the need for their protection. Relying on IUCN criteria, we can establish priorities in annihilating or at least mitigating unfavorable effects on the most endangered species.

The conservation of biological diversity requires cooperation and coordination with neighboring countries. Support should be given to efforts to explore shared concerns, exchange information, and coordinate biodiversity conservation plans with other countries of the Balkan Peninsula. Cooperative conservation projects can provide a positive focus for the region's peoples and contribute to the realization of a more secure and peaceful future for the Balkan Peninsula as a whole.

Such complex faunal studies in these regions undoubtedly represent a pioneer attempt to realize an integrated and coordinated analysis of the ecology, biogeography, taxonomic and ecological diversity, and systematic monitoring of the fauna of the Balkan Peninsula aimed at its adequate protection, conservation, and

improvement. Analysis and verification of the present status of this fauna at the turn of the millenium represents a great and responsible historical task.

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