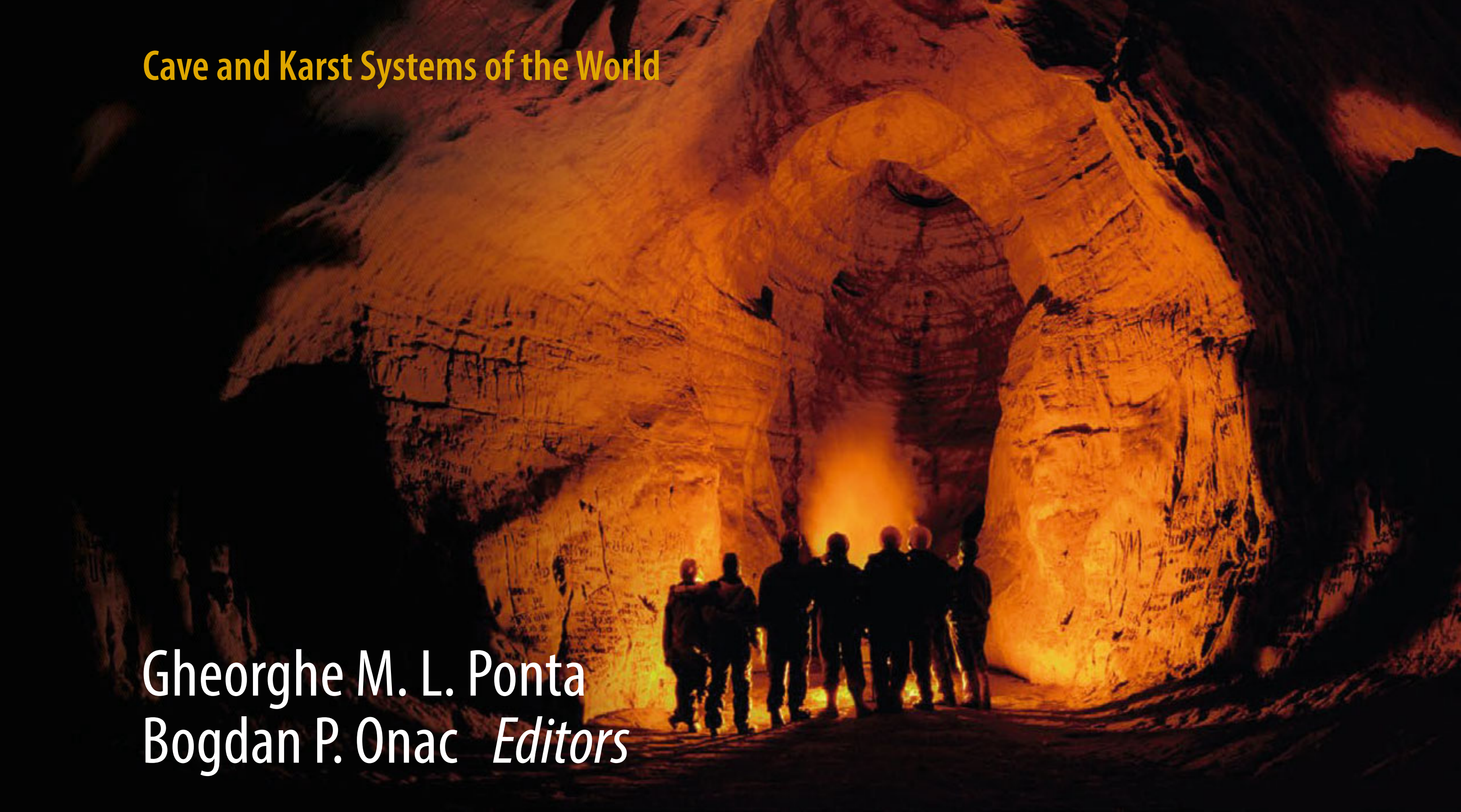

Cave and Karst Systems of the World

Gheorghe M. L. Ponta
Bogdan P. Onac *Editors*

Cave and Karst Systems of Romania

Springer

Cave and Karst Systems of the World

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To all cavers and scientists who have investigated the endlessly fascinating karst and cave world of Romania

Foreword

Limestones make up 4400 km^2 (1.8%) of Romania's surface, which apparently is not much but they still host all known types of karst landscape and more than 12,000 caves showing a variety of genetic and morphological features. There are active caves traversed by tumultuous rivers, caves at higher levels with quiet chambers and large detrital deposits, and walls that witness the various phases of riverbed deepening. At higher elevations are hydrologically dry cavities in which the water percolating from surface has generated spectacular speleothems that create the magnificent underground landscape that makes the caves famous.

Caves are developed in the three mountain chains, namely the East and South Carpathians, Apuseni Mountains, as well as close to the Black Sea in the southeastern part of the country, known as Dobrogea. With respect to their geological age, some of the limestones are Paleozoic, but the vast majority belong to the Mesozoic, most notably the Jurassic and Upper Cretaceous. They are part of the Alpine fold belts (Upper Cretaceous) and few are constituent of the Neozoic formations (especially Miocene).

In almost all limestones, natural cavities exist across the altitude scale from the sea level to over 1500 m in elevation. Caves are generally easily accessible, which explains why since ancient times they have been known by the inhabitants of these places, as evidenced by some documents of great value to show that the Romanian caving can boast a venerable past. Here are some examples:

Prehistoric/Neolithic artifacts, such as tools, pottery, and even skeleton remains, were found in many caves. Extraordinary are, for example, foot imprints discovered in hardened moonmilk or the invaluable cave paintings, dating back to more than 30,000 years, depicting animals (mammoth, horses, reindeers) and humans (possibly shamans). Another example of early use of caves was passed on through toponymy. For example, Peștera Zmeilor (Dragon Cave), which is famous for its skeletal remains of cave bears, was considered by locals as the resting place of fairy beings from the past. A valuable testimony is that of Pythagoras, who mentions that the Dacians (Romanian's ancestors) were immortal, since their King Zalmoxis who was apparently considered dead after a battle had in fact retreated into a cave and emerged after 10 years alive.

The first permanent dwellings in caves dates back to the times when monks started to use them as refuge, places of worship, or even as monasteries to defend the Christian faith against the plague of the Ottoman persecution. These are many, but just to name a few, the cave of Sfântu Grigore (St. Gregory) Decapolitul next to the Bistrița Monastery and the little church that was erected under the portal of the Ialomiței Cave (Bucegi Mountains), the foundation of which is lost in the darkness of time. Important is also the Sfântu Andrei (St. Andrew) Cave near Ion Corvin Village (Dobrogea), which was home of Apostle Andrew the Savior, who in the first century brought Christianity to the territory of the present-day Romania.

First scientific information about Romanian caves dates back to the eighteenth century and refers to geographical, geological, and archeological findings. The authors were generally speaking scientists, but it took some time before the information about caves gradually begins to penetrate into collective consciousness. This led to visits and exploration tours organized by curious adventurers, and thrill seekers, which were the forefathers of modern cave exploration that took off after World War II.

At the beginning of the twentieth century, a new scientific discipline of biology was born, namely the biospeleology. The founding father was the Romanian Scientist Emil G. Racoviță, who dedicated his life to the study of organisms living in caves and which, because of the permanent darkness, the high humidity, and the precarious food, have developed special anatomical and physiological abilities. He studied the fauna of over 1000 caves in France, Spain, Corsica, Algeria, Slovenia, and Romania, presenting them to the world. Recognized for his scientific merits, he has been appointed Professor at the University of Cluj (Romania), where on April 27, 1920, he founded the world's first speleological institute, meant to serve as a global center of biospeleology research with collaborators around the world. This fact brought Romania's speleology and caves into a privileged position. This book responds to the growing interest in cave and karst studies.

Simultaneously with the development of the speleology as a science, the more explorative and amateur caving movement took off. The many cavers organized themselves into various clubs and associations and begun a vast activity of exploration and mapping, thus boosting the speleological patrimony of the country. If in the 1930s there were roughly 500 known caves in Romania, nowadays there are more than 12,000! It is the merit of three generations of cavers, professionals (research institutes and universities), and amateurs (tourists, climbers) alike, who were extremely active after 1950.

In conclusion, I would like to say that I am happy that my name is present alongside the most well-known, knowledgeable, and performers of Romanian speleology.

Bucharest, Romania

Marcian Bleahu
Honorary Member of the Academy of Romanian Scientists

Preface

Romania has many unique karst landscapes and a great variety of caves as documented in this book, but is not a true karst country. The karst-prone rocks cover about 5500 km^2 representing only $\sim$2.3% of the total surface of the country and occur as scattered islands mainly along the Carpathians. After an introductory section that presents the general geological, hydrogeological, and karst settings of Romania, the book follows the geographic structure of the Systematic Catalogue of the Romanian Caves published by Goran in 1982. The presentations begin with caves located in the East Carpathians, continue along the South Carpathians, and then cover the Apuseni Mountains. The caves of the Someș Plateau and Dobrogea are described before the final section, which includes a number of specific topics, such as evaporite karst, ice caves, bat fauna, cave biology, show caves.

In Romania, the scientific interest in caves and karst dates back to 1776 when J. Fridvaldszky included in his famous treatise "*Mineralogia Magni Principatus Transylvaniae*," a detailed description of sulfur, alum, and calcite cave deposits. By the turn of the nineteenth century, professional geographers and geologists were conducting extensive field campaigns and described or mentioned in their publications karst and caves from Bihor Mountains, Vârghiș Gorges, and Banat. In 1907, the Romanian Biologist Emil G. Racoviță published the *Essay on biospeological problems,* widely considered the founding book of biospeleology. Soon after (1920), he established the world's first Speleological Institute in Cluj-Napoca, which truly catalyzed the systematic research of the Romanian caves. Between 1920 and 1956, sustained field campaigns conducted by E. G. Racoviță and his collaborators successfully described over 250 caves, the majority of them being documented in two volumes of the monograph *Enumération des grottes visitées* (Enumeration of visited caves).

Shortly after 1956, when the Institute of Speleology was reorganized carrying this time Emil Racoviță's name ("Emil Racoviță" Institute of Speleology (ERIS)), with offices in Bucharest and Cluj-Napoca, the recreational caving movement began in several major cities throughout Romania: Cluj-Napoca, Reşiţa, Bucureşti, Arad, etc. If in 1945 about 500 caves were known, the 1965 map of the Romanian karst regions published by ERIS included 984 caves. Their number increased exponentially to over 6800 by 1982, reaching about 12,300 in 2017. This significant increase was the result of the fact that in 1976, the amateur speleology movement receives the status of a sport discipline. As such, the Central Committee of Sport Speleology was formed as a subsidiary of the Romanian Federation for Tourism and Climbing, and an annual competition (Speosport) began between the caving clubs, which acquired points (and ranking) for each new cave discovered or meters of galleries added to known caves or shafts. After the totalitarianism regime collapsed in 1989, the cave exploration activities decreased significantly as Romania opened its borders and cavers found more attractive opportunities to travel and explore karst areas outside the country. However, a handful of gifted amateurs continue to work along with researchers in their mutual interests in caves, and this book has been prepared by both.

The reader must consider this book no more than an introduction to the cave and karst of Romania. It was written with the intention of capturing representative examples of caves, which host remarkable fauna, minerals, fossils, artifacts, human traces, or large perennial ice deposits. If none of these, then the caves and shafts were included simply because of their length or depth, passage morphology, volume of void, or peculiar speleogenesis. It is our hope this book will be a useful source of information and a stimulating introduction to the world of karst and caves, and entice readers to delve further into this captivating topic. The cooperation of the many authors (more than 70) has made the editor's tasks feasible. Spencer Coca, Joe Kearns, Oana Moldovan, Afina Lupulescu, John Mylroie, Arthur Palmer, and Robert Scharping are thanked for language corrections. This book would not have been possible without the support of the Springer International Publishing.

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The Founder of Biospeleology and World's First Speleological Institute

Gheorghe Racoviţă

Keywords
Cave • Biospeleology • Research • Cluj-Napoca
Romania

Racoviţă, Emil Gheorghe (born November 15, 1868, in Iaşi, deceased November 19, 1947, in Cluj) is a world-renowned Romanian biologist (Fig. 1), the founder of biospeleology as a scientific discipline and of the world's first speleological institute.

Emil, the son of Eufrosina and Gheorghieş Racoviţă, attended the primary school in Iaşi where he had I. Creangă as a teacher, and then, he continued at the "Institutele Unite" High School in the same city, being the student of P. Poni, A. D. Xenopol, and G. Cobălcescu. In 1887, he went to Paris to attend the Law School, but he also attended the lectures given by L. P. Manouvrier at the School of Anthropology, and then those at the Sorbonne School of Sciences, where he had as teachers, among others, the renowned zoologists H. de Lacaze-Duthiers and G. Pruvot. In 1889, he obtained his degree in Law, and in 1891, in Natural Sciences; in 1896, he was very successful in defending his doctoral thesis entitled *Le lobe céphalique et l'encéphale des Annélides polychètes (Anatomy, Morphology, Histology)*.

Since 1900, he has been working at the Arago Laboratory of Banyuls-sur-Mer (France) as Vice-Director and Lecturer at the Faculty of Sciences. On February 1, 1920, he has been appointed Professor of Biology at the Faculty of Sciences in Cluj (Romania), and in April 26, the Director of the Institute of Speleology. In the same year, he was elected Full Member of the Romanian Academy. In June 13, 1926, he gave his well-known reception speech *Speleology—a new science of the ancient subterranean mysteries*. For three consecutive years (1926–1929), he was elected

Fig. 1 Emil G. Racoviţă in 1921 (photograph from the archive of G. Racoviţă)

President of the Romanian Academy. Between 1922 and 1926, he was also a Senator of the University of Cluj and became its Rector during 1929–1930.

Emil Racoviţă started his naturalist activity during the years of his studies by conducting marine biology research at the Roscoff and Banyuls-sur-Mer oceanic stations. The work of this first period was part of his doctoral thesis and established him as a recognized biologist worldwide. As a result, he was chosen as a naturalist of the Belgian Antarctic Expedition, initiated and led by Marine Lieutenant A. de Gerlache de Gomery. Deployed on board the Belgica vessel between August 16, 1897, and November 18, 1899, this expedition completed Racoviţă's scientific formation in the same way the famous Beagle expedition helped C. Darwin crystallize his evolutionary theory. It was the first scientific expedition to be undertaken in the Antarctic, and the first that spend the winter at the extreme latitude of 71° 31′. The substantial contribution of the Romanian naturalist was reflected in the observations and studies carried out on marine birds and mammals, particularly on whales, as well as in the collection of a huge scientific material, from which more than 60 studies were published by various specialists.

Returned to France, Emil Racoviţă continued his marine biology research at Banyuls. On July 16, 1904, during a cruise on the Balearic Archipelago, he visited the famous Cueva del Drach (Dragon Cave) on Mallorca Island (Spain), where he discovered his first cave animal, an aquatic

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crustacean isopod that he will describe a year later under the name of *Typhlocirolana moraguesi*. Recognizing the importance of cave animals in deciphering the evolution processes, he started to dedicate to researches on the subterranean domain, laying the basis of a new scientific discipline—**biospeleology**. He formulated with remarkable clairvoyance its main aims and directions in the memorable *Essai sur les problèmes biospéologiques* (1907). With this work, he opened the series on subterranean biology published by zoologists around the world under the common title of "Biospeologica." Accompanied by his collaborator, R. Jeannel, he explored over 1000 caves in France, Spain, Corsica, Algeria, Slovenia, and Romania, collecting a significant faunistic material. Along with R. Jeannel, he initiated the first cadaster of the investigated caves, published in seven series under the title *Enumération des grottes visitées* (1907–1929).

In 1920, returning to his homeland at the request of the Transylvanian Dirigent Council, he founded the Institute of Speleology in Cluj, world's first scientific research institute dedicated to the study of the subterranean domain. The results of the researches were published in the journal *Lucrările Institutului de Speologie*, one of the most important speleological publications at that time. At the University of Cluj, he had a sustained and extensive activity in organizing the Society of Sciences (1920) who was the president until his death, and published the Bulletin of the Society (since 1921). He also initiated and led the first Congress of Naturalists in Romania (Cluj, April 18–21, 1928) and had an essential contribution in the elaboration of the first nature conservation law (July 4, 1930) and the establishment of the Committee on Natural Monuments (1931), who was the member until 1947. He was concerned in improving the organization and functioning of the University library by coordinating the publication of a *Catalog of scientific and medical journals* (1926). He was active in the Transylvanian Association for Romanian Literature and Culture (ASTRA) founded in Sibiu in 1861 and in which was active until 1946. E. Racoviță collaborated with the organization of the Ethnographic Museum in Cluj (1928) and the foundation of the first tourism society in Transylvania, the "Frăția Munteană" (1922).

Emil Racoviță's scientific work is marked by many valuable contributions to the progress of biology, new and bold ideas, some of which have preserved their validity to this day. He raised the systematics from the level of a descriptive discipline to the rank of applied phylogeny, considering that species can only be studied and understood in the context of their historical development, geographical distribution, and their ecological relations. He has set precise criteria for describing new species, by militating for the adoption of unique rules. He formulated an original definition of the species as "*... an isolated colony of consanguineous,*" thus summarizing the most important characteristics of this fundamental biological unit. He vigorously promoted the need for studies on homogeneous groups of animals, the so-called phyletic series, the only ones able to bring to light the true natural history of various taxonomic categories. Applying consistently such principles in his research on isopod crustaceans, he provided through numerous published papers, true models of scientific analysis. He brought to the world attention the complex problems of the subterranean domain, establishing its extension, the origin of the cave animals, and the ways of colonizing the cave habitats. He outlined the phases of biospeleological research development, anticipating from the beginning the transition from descriptive research to experimental research, carried out in laboratory setup inside caves. He formulated a series of basic principles, which have led to the formulation of the evolutionary neo-Lamarckist theory. He proposed replacing the classic notion of "species" with the more comprehensive "species line" that includes the entire historical sequence of forms that shaped the present species. He emphasized the particular role that geographic, ecological, or physiological isolation has in diversifying species by preserving and amplifying some small initial variations. He specified the evolutionary significance of the adaptation process, for which he proposed the more appropriate term "accommodating" and which he defined as the tendency of the bodies to achieve a perfect fit with their living environment. He introduced the notion of "seclusion" to designate the direct action of environmental factors (as opposed to the compensating reactions of adaptation), emphasizing on the decisive role played by evolution in the formation and improvement of the artificial environment. He also made important contributions in establishing nature conservation rules and environmental principles on which the establishment and management of nature reserves should be based.

Through his entire activity and undeniable value of his work, Emil Racoviță is among the most important Romanian scientists and is part of the great scientific and cultural personalities of the humanity. His merits are confirmed by the many titles and distinctions he was granted: Member (1893) and Honorary President (1925) of the Zoological Society of France; Knight of the Leopold Order of Belgium; Member of the Romanian Geographic Society (1899); Member of the Geography Society of Paris; Correspondent Member of the Society of Physicians and Naturalists of Iaşi (1900); Knight of the French National Order Legion of Honor (1902); Member of the Entomological Society of

France (1906); Correspondent Member of the Zoological Society and of the Royal Geographical Society of London (1910); Correspondent Member of the Society of Natural Sciences of Barcelona (1922); Honoris Causa of the University of Lyon (1923); Member of the Paris Biology Society (1925); Grand Officer of the Star of Romania Order (1928); Member of the Romanian Society of Geology (1930) and its President (1934); Member of the Spanish Society of Natural History (1930); President of the Society of Sciences of Romania (1932); Founding Member of the Paris Biogeography Society (1935); Correspondent Member of the Paris Medical Academy (1944); and Member of the Zoological Society of London (1947).

"Emil Racoviță" Institute of Speleology: World's First Research Unit Dedicated to Karst and Cave Studies

Ioan Povară

Keywords
Emil Racoviţă • Cave • Karst • Biospeleology
Cluj-Napoca • Romania

Introduction

The "Emil Racoviţă" Institute of Speleology (ERIS), ***first of its kind in the world***, performing research activity for more than 97 years, owns its existence to the initiative of the great scientist ***Emil G. Racoviță (1868–1947), a biologist, polar explorer, and founder of biospeleology***. The establishment of the ERIS became official when the Law no. 19.11 from April 26, 1920, was published in "*The Official Monitor of Romania*" (in Romanian: "*Monitorul Oficial*") no. 86 from July 20, 1920. The institute was founded as an independent research unit within the Faculty of Sciences at the University of Cluj, and E. G. Racoviţă served as Director and Manager between 1920 and 1947. The research trends initiated by E. G. Racoviţă were continued until 1949 by R. Jeannel and P. A. Chappuis, two close collaborators of the Romanian scientist. In 1951, within the Geological Committee of the People's Republic of Romania, two research groups were assembled in Bucharest and Cluj, respectively. Their mission was to prospect and identify phosphate deposits, an opportunity that led to the exploration of a large number of caves, which were simultaneously surveyed and investigated for their fauna.

On **June 21, 1956**, the Institute of Speleology was reorganized, under the leadership of Professor C. Motaş, within the Ministry of Education, and after a period in which it was successively subordinated to the Romanian Academy and the Ministry of Education, it moved under the aegis of the Romanian Academy, as a national research unit within the Biological Sciences Section (Government's Decision 656/June 5, 1990). Currently, the "Emil Racoviţă" Institute of Speleology is structured in four departments in Bucharest (Biospeleology and Karst Edaphobiology; Geospeleology and Paleontology; Karstology, Karst Inventory, and Protection; Hydrogeochemistry) and one in Cluj-Napoca that includes researchers in both geo- and biospeleology fields.

"Emil Racoviţă" Institute of Speleology conducts high-quality theoretical and applied research on karst and cave issues. Its research activities combine the local and regional perspective with a global application. The main *fields of cave research* include:

- Taxonomic, phylogenetic, biogeographic, and ecological studies of subterranean environments, aiming to highlight their diversity and complexity;
- Mineralogical and geochemical studies;
- Quaternary climate oscillation reconstructions based on speleothems, ice, and guano deposits;
- Studies of the fossil mammal fauna;
- Study of the karst system complexity and distribution, and regional karst research;
- Karst environment protection/conservation and its vulnerability to pollution: The Hydrogeochemistry Laboratory (ISO/CEI 17025:2005 accredited) is able to analyze groundwater and surface water samples.

During the institute almost 100 years of activity, its researchers have published more than 2000 papers in Romanian and international scientific journals, more than 300 books at well-known national and international publishing houses, out of which 40 received various awards. More than 150 national and/or international research projects have been undertaken, and 62 scientific meetings have been organized.

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- Peşteri din România (*Caves of Romania*) (1976);
- Modelling of the chemical speciation in natural aqueous systems;
- Peşteri din România. Ghid turistic (*Caves of Romania. Tourist guide*);
- Carstul Munţilor Pădurea Craiului (*The karst of the Pădurea Craiului Mountains*);
- Peşteri scufundate (*Submerged caves*);
- Chiroptere din România (*Chiroptera of Romania*);
- Geologia regiunilor carstice (*The geology of karst terrains*);
- Biodiversitatea în mediile subterane din România (*Biodiversity of the subterranean environments of Romania*);
- Masivul Piatra Craiului (*Piatra Craiului Massif*);
- Scărişoara Glacier Cave. Monographic study (*Romanian Academy Award 2004*);
- Coleoptera din peşteri. Adaptări, texonomie, ecologie, feromoni, comportament, protecţie (*Coleoptera in caves. Adaptations, taxonomy, ecology, pheromones, behavior, protection*);
- Fauna României, Insecta, Coleoptera (*Romania's Fauna*, "*Insecta*", *Coleoptera*) (vol. X, fasc. 6);
- Encyclopaedia Biospeologica (*3 volumes*);
- The first ecological reconstruction of underground environment from Romania—Cioclovina Uscată Cave;
- Diversitatea lumii vii (*The diversity of the living world*);
- Life and death at Peştera cu Oase. A setting for Modern Human emergence in Europe (Oxford University Press);
- Valea Cernei. Morfologie, hidrologie, ape termale (*Cerna Valley. Morphology, hydrology, thermomineral waters*);
- Reconstituiri paleoclimatice pe baza mamiferelor mici din depozite carstice. Studiu de caz—Dobrogea Centrala (*Paleoclimate reconstructions based on small mammals from karst deposits. Case study: Central Dobrogea*);
- Fauna României, Chiroptera (*Romania's Fauna, Chiroptera*);
- The paleontology of the cave bear bone assemblage from Urşilor Cave of Chişcău—Osteometry, palaeoichnology, taphonomy, and stable isotopes (*Romanian Academy Award 2015*);
- Ice caves (Elsevier).

The biospeleological expeditions with results published by the Romanian Academy include: *Bulgaria 1983*; *Cuba* (4 volumes entitled "*Résultats des expéditions biospéologiques cubano-roumaines à Cuba*"); speleological expedition to *Venezuela*; and the expedition to *Israel*, for collecting cave and soil fauna (*Soil fauna of Israel*).

Over the last 15 years, the scientists from the ERIS have conducted important research activities that translate in 482 papers and 49 books published; 470 international scientific meetings attended; 22 national and international scientific meetings organized; 62 contracts and 14 Romanian Academy and Romanian Science Foundation (UEFISCDI) awards received. The research activities are supported by laboratories equipped with state-of-the-art facilities, operated by specialists from all ERIS's departments.

The most important research grants during these recent years were focused on:

- monitoring the conservation status of caves and bats species or the human impact on show caves;
- karst and related terrains vulnerability in Romania;
- climate archives in karst—an integrated approach to the study and modeling of abrupt climate oscillations;
- chemical reactions within the cave environment: mineralogical, geochemical, and geochronological aspects;
- paleoclimate reconstructions based on interdisciplinary studies of ice deposits from caves of Romania;
- stable isotope signature in cave guano as archive of past environments;
- identification of hypogene caves on Cerna Valley (Romania) based on stable isotope analysis;
- remote connections during the climate changes from Western and Eastern Europe, based on contemporaneous speleothem climate archives, dated to the last interglacial;
- thermal system resilience to anthropogenic and natural disturbances;
- the development of the "*Natura 2000*" network;
- the diversity and the metabolic activity of the ice caves microbiome, as a response to climate changes and to the anthropogenic activity.

The "Emil Racoviţă" Institute of Speleology of the Romanian Academy is currently collaborating with more than 15 Romanian institutions (e.g., Institute of Biology, “Grigore Antipa” National Museum of Natural History, National Institute for Research and Development in Tourism, University of Bucharest, “Babeș-Bolyai” University in Cluj-Napoca, Academy of Agricultural and Forestry Sciences “Gheorghe Ionescu-Şişeşti”) and more than 30 foreign partners (University of Melbourne, University of Miami, University of Bergen, University of Bremen, University of South Florida, Chinese Institute of Zoology, Royal Belgian Institute of Natural Sciences, Department of Evolutionary Biology and Environmental Studies at the University of Zürich, Institute of Soil Biology from České Budějovice, Polish Geological Institute, Stuttgart State Museum of Natural History, Natural History Museum from Verona, etc.).

Being committed to improving the knowledge and the protection of the subterranean realm, the “Emil Racoviță” Institute of Speleology has organized yearly the following scientific and applied field courses to educate young cavers: *National School of Biospeleology, National School of Chiropterology, National Stage of Subterranean Surveying and Mapping, National Stage of Karstology and Geospeleology, and National Field Karstology Studies*. At the same time, ERIS provides environmental consulting assistance to apply its own research findings to improve cave and karst resource management.

Since its establishment in 1920 as the world’s first cave research entity, the “Emil Racoviță” Institute of Speleology has been a leading international center for karst and cave research. The mission of ERIS is to design, conduct, educate, and disseminate research findings worldwide. ERIS’s mission and vision for the future is to continue its dynamic national, regional, and international leadership in cave and karst research to help policymakers, educators, and the general public to properly manage karst waters, karst landscapes, and their biospeleological and physical resources.

Geology of Romania

Ioan Balintoni

Abstract

Located at the southwestern end of the Trans-European Suture Zone (TESZ), the territory of Romania includes several major Alpine terranes of East European (Moldavian and Scythian platforms) or of West European affinity (Foreapulian, Getic, Euxinic terranes and the North Dobrogean Orogen). The pre-Alpine terranes from the basement of the Alpine terranes of West European affinity have a peri-Gondwanan provenance of Avalonian type (late-Neoproterozoic peri-Amazonian), Cadomian type (late-Neoproterozoic peri-North-African), or Carpathian type (essentially Ordovician, peri-North-African). Carpathian-type terranes were described in the Apuseni Mountains (Someş, Biharia, Baia de Arieş), in East Carpathians (Bretila, Tulgheş, Negrişoara, Rebra), and in the Getic Domain of South Carpathians (Cumpăna upper unit of the Sebeş-Lotru Terrane, Leaota, Bughea, Caraş, Padeş, Făgăraş). Cadomian type includes the Lotru lower unit of the Sebeş-Lotru Terrane. Drăgşan and Lainici-Păiuş terranes from the Danubian Domain of South Carpathians, the Histria and Altîn Tepe from Central Dobrogea, the east Moesia from South Dobrogea and Boclugea, Megina, Orliga, Uzum Bair from the basement of the North Dobrogean Orogen are all Avalonian type. The carbonate rocks are important in the basement of Baia de Arieş, Negrişoara, Rebra, Făgăraş, and Lainici-Păiuş terranes. The Mesozoic carbonate rocks anterior to the Alpine terranes amalgamation cover significant surfaces in the Carpathians and Dobrogea, where Romania's main karst regions occur. Karst-like features are also known on evaporites of Cenozoic age occurring in the Transylvanian Basin and Carpathian foreland.

Keywords

Carpathian peri-Gondwanan Terranes • Euxinin Terranes European Craton • Scythian Platform • North Dobrogean Orogen

Introduction

For more than a century, Romanian geologists have focused their research in collecting detailed information (geology, geophysics, tectonics, etc.) needed in developing geological maps and models. To our knowledge, only two Romanian geology overviews are written in English (Burchfiel and Bleahu 1976; Săndulescu 1994), and all the others are exclusively in Romanian (Oncescu 1957; Mutihac and Ionesi 1974; Săndulescu 1984), thus hidden behind a language barrier. Several new publications dealing with local and regional studies contribute substantially to developing a deep understanding of the Romanian geologic history. Many of these studies are cited within this chapter, which provides a very detailed presentation of the crystalline basement units (spatial distribution, orogenic epochs, ages, etc.) on which rest the sedimentary cover, including the karst-forming rocks.

The territory of Romania is located at the south-eastern end of the Trans-European Suture Zone (TESZ) (e.g., Pharaoh 1999; Fig. 1) and includes geotectonic units associated with both the East European Craton (EEC) and Western Europe, the latter one of peri-Gondwanan provenance. With respect to the Alpine structure of Romania, several major terranes (geological units) with pre-Alpine lithospheric basement can be identified (Fig. 2). Using the terminology proposed by Balintoni (1997), these are:

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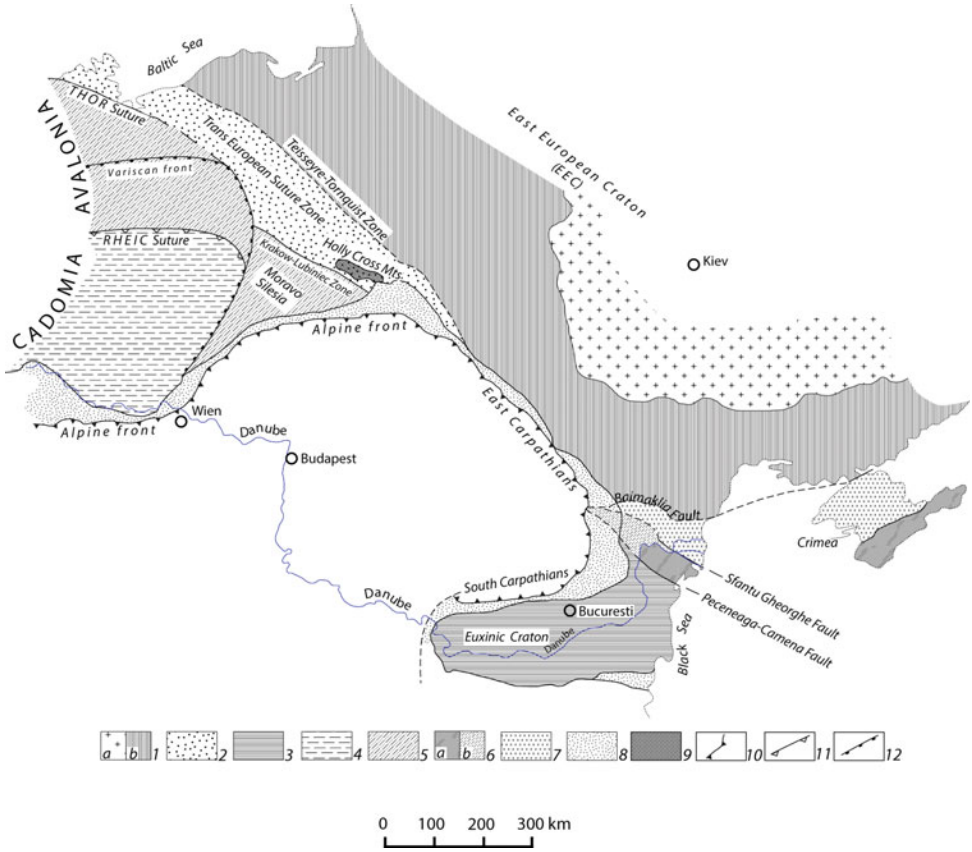
Fig. 1 Sketch map of the TESZ and adjacent areas. Compiled from Săndulescu (1984), Balintoni (1997), Pharaoh (1999). *1* East European Craton (a Ukrainian Shield, b platform cover), *2* Trans-European Suture Zone, *3* Euxinic Craton, *4* Cadomia, *5* Avalonia, *6* North Dobrogean–Crimean Orogen (a outcrop, b covered), *7* Scythian Platform, *8* Carpathian Foreland Basin, *9* Holy Cross Mountains, *10* Alpine Front, *11* Rheic Suture, *12* Variscan Front



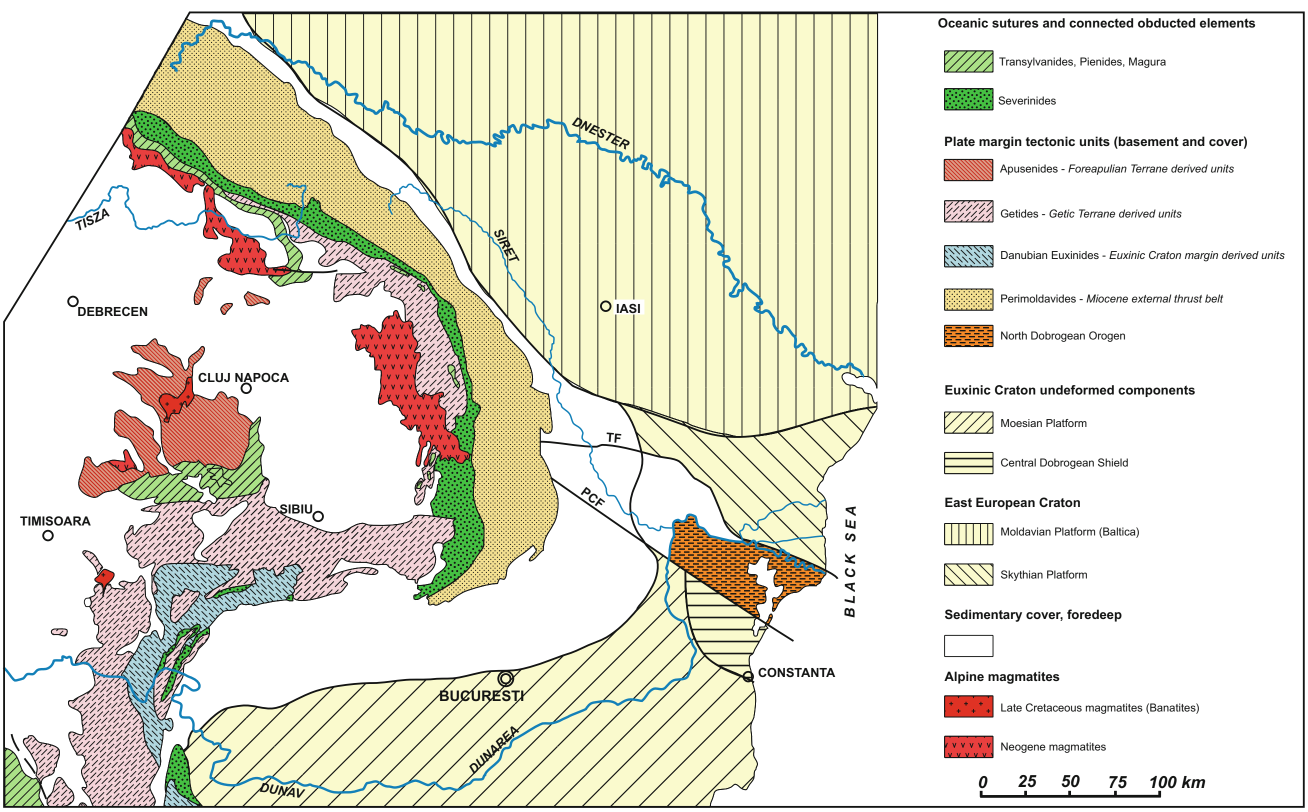


Fig. 2 General Alpine structure of the Romanian territory compiled from Săndulescu (1984) and Balintoni (1997)

(1) Intensely deformed terranes:
  (a) the Getic Terrane with the East Carpathians and the Getic Domain of South Carpathians as major components
  (b) the Foreapulian Terrane with the Apuseni Mountains
  (c) the North Dobrogean Orogen.
(2) Marginally deformed terranes: the Euxinic Terrane with its Danubian Domain of South Carpathians.
(3) No visible deformed terranes: the EEC and its south-western margin, the Scythian Platform.

Except the EEC, the basements of the other terranes have a peri-Gondwanan (peri-Amazonian or peri-North-African provenance (Nance et al. 2008). The European peri-Gondwanan terranes record post-Grenvillian thermo-tectonic events associated with the Pan-African (Avalonian-Cadomian), Caledonian, North-African Ordovician, and Variscan orogenies, or they were generated during these orogenies (e.g., Nance et al. 2008; Balintoni and Balica 2013).

In Alpine terms, the Moldavian Platform (the western margin of EEC) represents the East Carpathians foreland and the Euxinic Terrane is the foreland of the South Carpathians. The North Dobrogean Orogen thrusting over the south-western margin of EEC, the Scythian Platform forms its foreland. Solving the history of the Alpine terranes is an intricate task that includes: the identification of the pre-Alpine terranes from the basement of the Alpine ones and understanding their pre-Alpine history and the recognition of the Alpine sediments anterior and posterior to the Alpine terranes amalgamation. In addition, the Alpine terranes history also incorporates an extensive magmatism, well known in the western part of Romania (the banatites) and in the western volcanic chain of the East Carpathians.

Boundaries of the Alpine Terranes

Săndulescu (1984, 1994) proposed a largely accepted model of the Alpine continental and oceanic units on the Romania territory and around it. According to this author, between the Foreapulian and Getic terranes, the main Tethyan Suture Zone remnants are visible. Also, in the front of the Getic Terrane are known the remnants of the Severin rift or ocean. Between the Severin rift remnants and Peceneaga–Camena Fault is situated the Euxinic Terrane, and the North Dobrogean Orogen overthrusts the Scythian Platform between Peceneaga–Camena and Sf. Gheorghe faults.

Schmid et al. (2008) use for the Forealpine Terrane the name of Tisza, for the Getic Terrane the name of Dacia, and Moesia for the Euxinic Terrane. The Tisza and Dacia terranes separated each other and against the surrounding terranes by branches of the Alpine Tethys. The Alpine Tethys branches between the Tisza and Alcapa terranes and Tisza and Dacia terranes are connected by great faults with the Meliata–Maliac Ocean and farther with the Neotethys. The terminal part of Alpine Tethys between Dacia Terrane and the eastern continental blocks is called the Ceahlău–Severin Ocean. As a conclusion we remark that overall the two models are similar, recognizing on the territory of Romania the same number of continental blocks and oceanic branches.

The Basement of the Alpine Terranes

The Foreapulian Terrane

Balintoni et al. (2010a) separated in the basement of the Foreapulian Terrane from the Apuseni Mountains the following pre-Alpine terranes: Someş, Baia de Arieş, and Biharia. The zircon LA-ICP-MS U/Pb ages on orthogneiss and metagranitoid samples from the basement of these terranes yielded early Paleozoic protolith ages (Table 1). Except a late Cambrian age yielded by the Biharia Terrane metagranites, the other ages are early to middle Ordovician. These results suggest an Ordovician orogeny for the geotectonic context in which the above terranes have been generated (Balintoni and Balica 2013). The Someş Terrane rocks (dominantly orthogneisses and paragneisses) suggest a tectonic setting of active plate margin, whereas the Biharia Terrane rocks, essentially metabasites and metagranites, indicate a rift environment. The Baia de Arieş lithology that includes large limestone lenses is interpreted as passive plate margin deposits. The metamorphic mineral associations in the Someş, Biharia, and Baia de Arieş terranes rocks suggest two metamorphic events: First of them is probably of Ordovician age, while the latter one, with an intricate thermal path, is Variscan.

The Getic Terrane

The Getic Terrane in East Carpathians

Balintoni and Balica (2013) found in the basement of the Crystalline-Mesozoic Zone the following pre-Alpine terranes: Bretila, Tulgheş, Negrişoara, and Rebra. Likewise Apuseni Mountains, the zircon LA-ICP-MS U/Pb ages on ortho-rocks sampled from these terranes yielded Ordovician ages (Table 2). Thus, the East Carpathians pre-Alpine terranes also originated during an Ordovician orogenic event. The same authors consider the Bretila Terrane a continental margin magmatic arc (rock assemblage of metagranite, orthogneiss, paragneiss, and amphibolite); the Tulgheş Terrane should expose the mixed infill of a back-arc basin (basinal rock assemblage with thick black quartzite lenses and associates manganese ore bodies, followed by recurrent metarhyolite layers with Kuroko-type base metal ore bodies); the Rebra and Negrişoara terranes are interpreted to constitute the inboard continental margin characterized by metaterrigenous layers, thick carbonate rock layers containing Mississippi Valley-type syngenetic mineralizations, and occasional distal metavolcanic layers. The metamorphic history of the East Carpathians terranes is similar with that of the Apuseni Mountains: a pre-Variscan metamorphic event and a convoluted Variscan thermo-tectonic history. The Bretila Terrane in the East Carpathians can be correlated with the Someş Terrane in Apuseni Mountains, whereas Negrişoara and Rebra terranes with Baia de Arieş. The Tulgheş Terrane in East Carpathians suggests an evolved stage from a rift to a back-arc basin.

The Getic Terrane in South Carpathians (Getic Domain)

Balintoni et al. (2010b, 2014a) described in the Getic Domain of South Carpathians the following pre-Alpine terranes: Sebeş–Lotru, Leaota, Bughea, Caraş, Padeş, and Făgăraş. The U/Pb zircon ages of the igneous protoliths from these terranes are listed in Table 3. The Sebeş-Lotru Terrane has a composite structure with a lower unit (Lotru) and an upper unit (Cumpăna) of late Neoproterozoic and Ordovician age, respectively. The other five terranes are Ordovician in age similar to the ones from the Apuseni Mountains and East Carpathians.

The Sebeş–Lotru, Leaota, and Caraş terranes originated in a magmatic arc tectonic setting (the quartzite and carbonate rocks are quite scarce, mica schist subordinate, paragneiss locally important, and rock assemblage is

Table 1 U/Pb zircon ages of the igneous protoliths from the peri-Gondwanan, Carpathian-type terranes in the basement of the Apuseni Mountains

Terrane	Metamorphic unit	Sample codes and types	Best age (Ma)
Someş	Someş	165, 166 Iara orthogneiss	459.8 ± 2.7
Baia de Aries	Baia de Arieş	171 Pociovaliştea augen gneiss	470.8 ± 5.0
		186, 268-9 Lupşa metaporphyroid	467.8 ± 3.8
		178 Mihoeşti metagranite	467.8 ± 4.7
		181-Muncelu metagranite	467.1 ± 3.9
Biharia	Biharia	170, 290, 291 Biharia metagranite	495.0 ± 2.1
		327, 328, 328b Biharia metabasite	477.8 ± 3.2

Table 2 U/Pb zircon ages of the igneous protoliths from the peri-Gondwanan, Carpathian-type terranes in the basement of the East Carpathians

Terrane	Metamorphic unit	Sample codes and types	Best age (Ma)
Bretila	Bretila	255-Anieş augen gneiss	464.0 ± 3.0
		257-Hăghimaş granitoid	469.2 ± 6.5
Tulgheş	Tulgheş	10-476-Zugreni metarhyolite	462.6 ± 3.1
Negrişoara	Negrişoara	10-475-Pietrosu porphyroid	461.1 ± 5.2
Rebra	Rebra	256-Nichitaş orthogneiss	447.9 ± 2.8

Table 3 U/Pb zircon ages of the igneous protoliths from the peri-Gondwanan Cadomian-type (Lotru metamorphic unit) and Carpathian-type (the other metamorphic units) terranes in the basement of the Getic Domain (South Carpathians)

Terrane	Metamorphic unit	Sample codes and types	Best age (Ma)
Sebeş–Lotru	Cumpăna	271-Căpâlna orthogneiss	458.9 ± 3.5
		283-Latoriţa orthogneiss	466.0 ± 4.2
	Lotru	279-Godeanu migmatic dyke	549.3 ± 3.9
		275-Frumoasa metagranite	587.5 ± 3.8
Leaota	Lereşti	221-Clăbucet orthogneiss	479.0 ± 5.2
		224-Lalu metagranite	475.0 ± 4.6
Caraş	Caraş	220-Naidăş metagranite	481.7 ± 3.2
	Bocşiţa-Drimoxa	215-Brădeşti metagranite	479.1 ± 2.7
Padeş	Padeş	239-Veţel orthogneiss	450.5 ± 2.9
Bughea subduction complex		223-Albeşti metagranite	467.8 ± 5.9

dominated by orthogneiss, granitoid, metabasite, and metaultrabasite). The Padeş Terrane origin is in a back-arc environment as that of the Tulgheş Terrane from East Carpathians. The Făgăraş Terrane, typical for passive continental margin environment, comprises metaterrigenous rocks (mica schist, paragneiss, quartzite), sometimes amphibolite, and especially thick layers of carbonate rocks that host Cu–Pb–Zn and magnetite mineralizations. The Bughea Terrane, located in the eastern part of the South Carpathians, marks a structural boundary of Variscan age between the Sebeş-Lotru Terrane in lower position and Leaota Terrane in upper position. It consists of a predominantly semipelitic to mafic melange and the associated Albeşti Granite of Ordovician age.

Except the Lotru unit of the Sebeş-Lotru Terrane of end-Neoproterozoic Cadomian-type, all the other ones record an initial pre-Variscan Ordovician metamorphic history, followed by a Variscan complex evolution, including an eclogite event for the Sebeş-Lotru and Bughea terranes. In accordance with their petrology, the Getic Domain pre-Alpine terranes can be correlated with those of East Carpathians and Apuseni Mountains.

The Carpathian terranes of Cambrian–Ordovician age and North-African provenance were named by Balintoni and Balica (2013) and Balintoni et al. (2014a) "Carpathian-type" terranes.

The Euxinic Terrane

As a continental lithospheric block, the Euxinic Terrane exemplifies a pre-Alpine craton, built up by the Moesian Platform, the Central Dobrogean Shield, and the Danubian Domain of South Carpathians, this one strongly deformed during the Variscan and Alpine orogenies (Balintoni 1997).

The Euxinic Terrane in South Carpathians (Danubian Domain)

Its basement consists of two pre-Alpine terranes: Drăgşan and Lainici-Păiuş (Liegeois et al. 1996; Balintoni et al. 2011a). The Drăgşan Terrane is a composite one, comprising a lower orthogneiss assemblage (Făgeţel), a middle metabasic–ultrabasic assemblage (Straja) and an upper mica gneiss unit (Dobrota) (Berza and Seghedi 1975). An orthogneiss sample from the Făgeţel assemblage yielded an U/Pb age of 808.6 ± 1.9 Ma (Balintoni et al. 2011a). For the Straja assemblage, Balica et al. (2014a, b) published four U/Pb ages of 501 ± 1.3, 516.7 ± 3.3, 578 ± 1.5, and 621.1 ± 4.5 Ma. According to Liegeois et al. (1996), the Straja assemblage of the Drăgşan Terrane has an intra-oceanic origin (an island arc). In this case, the Făgeţel assemblage probably represents a fragment of the continental margin to which the Straja assemblage docked; the Dobrota assemblage suggests a post-docking sedimentary cover.

The Lainici-Păiuş Terrane basement was divided into a lower "Carbonate-Graphitic" Formation consisting of marble, graphite mica gneiss, amphibolite, and calc-silicate gneiss, and an upper "Quartzitic and Biotite-Gneiss" Formation with minor marble, graphite mica gneiss, amphibolite and calc-silicate gneiss (Berza 1978). In accordance with these rock assemblages, the Lainici-Păiuş Terrane basement suggests an initial passive continental margin origin. However it became an active one later, how is documented by the Tismana, Suşiţa, Novaci, Olteţ, and Arsasca granitoid plutons with ages between 601.0 ± 2.2 and 587.4 ± 1.3 Ma (Table 4) intruding the Lainici-Păiuş Terrane basement (Balintoni and Balica 2012). The deposition age of metasedimentary rocks are older than ca. 600 Ma (the age of Tismana pluton) and younger of ~622 Ma, the age of the youngest detrital zircon grain found in a metaquartzitic sample (Balintoni et al. 2011a).

The initial metamorphic history of the Danubian Domain terranes is associated to the late Neoproterozoic Avalonian–Cadomian orogenic belt. The Drăgşan Terrane shows a medium grade initial metamorphic event, and the Lainici-Păiuş Terrane basement contains low-pressure and high-temperature metamorphic parageneses (Berza and Seghedi 1983). During the Variscan orogeny when the Danubian Domain was an upper plate, several granitoid plutons intruded its basement (Table 5, from Balintoni et al. 2014a). According to Balintoni et al. (2011a), the Danubian Domain terranes have an Avalonian provenance.

Table 4 U/Pb ages of the Cadomian granitoid plutons in the basement of the Lainici-Păiuş Avalonian terrane, the Danubian Domain (South Carpathians)

Terrane	Pluton name	Best age (Ma)
Lainici-Păiuş	Tismana	600.5 ± 4.4
	Suşiţa	588.1 ± 3.1
	Novaci	591.5 ± 4.1
	Olteţ	587.3 ± 2.6
	Arsasca	595.8 ± 7.2

Table 5 U/Pb ages of the Variscan granitoid plutons in the basement of the Drăgşan and Lainici-Păiuş Avalonian terranes, the Danubian Domain (South Carpathians)

Pluton name	Best age (Ma)
Retezat	309.7 ± 5.1
Buta	303.7 ± 2.4
Parâng Latoriţa	285.7 ± 1.8
Parâng Jieţ	297.7 ± 3.4
Culmea Cernei	286.8 ± 4.2
Frumosu	303.4 ± 2.9
Furcatura	316.4 ± 2.9

The Euxinic Terrane in Central Dobrogea (Central Dobrogean Shield)

In central Dobrogea, the basement of the Euxinic Craton crops out and is bounded by the Peceneaga–Camena and the Capidava–Ovidiu faults in north and south, respectively. The Central Dobrogean Shield consists of two tectonic units: the lower Altîn Tepe Group (Krautner et al. 1988a, b) made up of metasediments metamorphosed up to the amphibolite facies, and upper, very low-grade Histria Formation turbidites (Seghedi and Oaie 1995). Balintoni and Balica (2016) consider the two rock assemblages as terranes. The Histria Terrane was interpreted to be Ediacaran based on the medusoid *Nemiana simplex* Palij imprint (Oaie 1992). This age was confirmed by subsequent work of Zelazniewicz et al. (2009) and Balintoni et al. (2011b), both papers reporting detrital zircon ages between 633 and 579 Ma. Regarding the age of the Altîn Tepe Terrane basement, the youngest detrital zircon ages peak of 512 Ma reported by Balintoni and Balica (2016) suggests a maximum late Cambrian deposition age for it. The Histria Terrane does not show a Phanerozoic metamorphic history, and its rock assemblages suggest passive continental margin deposits. The initial metamorphism of the Altîn Tepe Terrane basement was probably Ordovician, connected to the Caledonian history of the Euxinic Craton margin.

The Euxinic Terrane in South Dobrogea (East Moesia)

In South Dobrogea, the basement of the Moesian Platform is covered by sediments and it was intersected only by boreholes. According to Seghedi et al. (2005), the pre-Jurassic Palazu thrust fault brings over the Histria Formation three discordantly superposed sequences of metamorphic rocks with different histories; from down to up these are Ovidiu Group (granite gneiss cut by pegmatite veins), the Palazu Group containing a banded iron formation (BIF), and the Cocoşu Group (volcano-sedimentary association). Balintoni et al. (2014b) reported for the Ovidiu Group granite gneiss two U/Pb Archean ages of 2781 ± 43 and 2895 ± 62 Ma. These are the first Archean ages obtained on the Romanian territory. The Moesian Platform basement was also penetrated by boreholes in the Romanian Plain (metamorphic and magmatic rocks), but no protolith ages were generated until now. Considering all the above information on the Euxinic Craton basement, a rather complex structure and history are evident; this is what characterizes the old continental fragments.

The Tişoviţa Terrane

The Tişoviţa Terrane basement is a mafic–ultramafic rock assemblage described as an ophiolite, and until recently it was considered to indicate the suture between the Drăgşan and Lainici-Păiuş terranes (e.g., Krautner 1996–1997). However, new isotopic data on rocks from its basement and the correspondent Deli Jovan and Zaglavak massifs, south of Danube (Zakariadze et al. 2006; Plissart et al. 2012; Balica et al. 2014b) restricted its age at middle Devonian. Concomitantly, Negulescu et al. (2014) established the Variscan age of the medium- to high-grade metamorphism affecting the Poiana Mraconia tectonic unit basement, which is thrusted over the Tişoviţa Terrane. Because such metamorphic event characterizes the Sebeş-Lotru Terrane basement (Medaris et al. 2003), subducted under the Danubian Domain basement, very probably the Tişoviţa Terrane is a remnant of the Rheic Variscan suture between the Getic Terrane basement and the Danubian margin of the Euxinic Terrane basement.

The North Dobrogean Orogen

The basement of the North Dobrogean Orogen consists of four pre-Alpine terranes, known as Boclugea, Megina, Orliga, and Tulcea (e.g., Seghedi 2012). Because "Tulcea" is also the name of a Cimmerian tectonic unit, we propose the name of "Uzum Bair" Terrane for the metamorphic basement of Tulcea tectonic unit, a place where it crops out.

Boclugea Terrane basement consists of quartzites and phyllites, an assemblage of biotite grade metasediments (Seghedi 2012). The Hamcearca and Chetros granite bodies around 600 Ma intruding the Boclugea Terrane basement (Balintoni et al. 2013) attest its Neoproterozoic age.

Megina Terrane basement is dominated by amphibolites and orthogneisses (Seghedi 2012). Two orthogneiss samples yielded U/Pb ages around 510 Ma (Balintoni et al. 2013); thus, the Megina Terrane basement is younger than the one of the Boclugea Terrane. Its initial metamorphism is probably early Ordovician, because it is covered by Paleozoic sediments beginning with the Priopcea quartzites, apparently of middle to late Ordovician age (Balintoni et al. 2013).

Orliga Terrane basement consists of micaceous quartzites with subordinate paragneiss, metabasic rock, and marble, the metamorphic degree reaching the sillimanite zone (Seghedi 2012). An Orliga metaquartzite yielded a group of U/Pb ages on detrital zircon around 510 Ma (Balintoni et al. 2010c). This is the maximum possible age of its rock assemblages. The initial metamorphism of Orliga basement happened during the Variscan thermo-tectonic events (Balintoni et al. 2010c, 2013).

The age of the *Tulcea Terrane* basement is not known, but the Agighiol Granite of ca. 300 Ma (unpublished data) proves it was involved in the Variscan orogeny. The pre-Alpine history of the North Dobrogean Orogen basement components is complicate and poor understood until present. The above-presented data attest Avalonian–Cadomian (Boclugea), Caledonian (Megina), and Variscan (Orliga) metamorphic events. During the Variscan orogeny, the Boclugea, Megina, and Uzum Bair terranes were altogether in the position of upper plate and the Orliga Terrane in that of lower plate. Detrital zircon data (Balintoni and Balica 2016) attest a peri-Amazonian provenance for all the North Dobrogean Orogen pre-Alpine terranes.

The East European Craton

In Romania, the East European Craton components are presented by the *Scythian* and *Moldavian* platforms. The first one is located southward of the Moldavian Platform, and it is separated from this unit by the Baimaklia Fault (Seghedi 2012). At surface, the Sf. Gheorghe Fault constitutes its boundary with the North Dobrogean Orogen (Seghedi 2012). Beneath the North Dobrogean Orogen it is continuing until the Peceneaga–Camena Fault (Săndulescu 1994). The basement of the Scythian Platform in this region consists of magmatic rocks, granite, diorite, and gabbro that yielded K/Ar ages of 790 and 640–620 Ma (Neaga and Moroz 1987). The magmatic basement is unconformably overlain by undeformed Vendian deposits. According to this description, no similarities exist between the basements of the Scythian Platform and the North Dobrogean Orogen components.

The *Moldavian Platform* represents the western part of the East European Craton. It is dipping by normal faults, beneath the East Carpathians thrusting front; thus its margin is not known. The basement of the Moldavian Platform was intercepted by drillings. A description of its basement is provided by Ionesi (1994): plagioclase paragneiss with almandine and sillimanite, or biotite and hornblende; orthogneiss with oligoclase and microcline, sometimes with ocular structure; pink granite with muscovite and biotite. Balintoni et al. (2014c) sampled two drill cores and dated the orthogneisses by zircon U/Pb LA ICP MS method. One sample yielded a Concordia age of 2071 Ma and the other a Concordia upper intercept of 2072 Ma. These ages are bracketed by the interval indicated by Kuznetsov et al. (2010) for the undifferentiated complexes surrounding the Archean nuclei of Sarmatia.

The Pre-Permian Covers of the Pre-Alpine Terranes Basement

The Foreapulian Terrane Components

In the Apuseni Mountains is known a pre-Permian cover on the Biharia Terrane basement, called the Păiuşeni Lithogroup (Balintoni 1997). It is very low-grade metamorphosed and consists of metaconglomerates and metapsamites, subordinate metapelites, alternating with metamagmatites that vary from basic to acid rocks. Their age is post-Ordovician and can be associated with a Variscan active plate margin.

The Getic Terrane Components in East Carpathians

In the East Carpathians, there is a pre-Permian cover on the Bretila Terrane basement (Krautner and Krautner 1970). Lithologically, it consists of basic metavolcanics and metasediments that include conglomerates and phyllitic rocks, white and black quartzites, and limestones. Balintoni (1997) called this sequence the Rodna Lithogroup. As in the Apuseni Mountains, the Rodna Lithogroup is the cover of a Variscan active plate margin.

The Getic Terrane Components in South Carpathians

In the South Carpathians, Balintoni (1997) describes the pre-Permian Banat Lithogroup, supposedly in genetic relationship with the Sebeş-Lotru Terrane. The Banat