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Maria Rădoane
Alfred Vespremeanu-Stroe *Editors*

Landform Dynamics and Evolution in Romania

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Landform Dynamics and Evolution in Romania

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Preface

Everybody knows about landforms. They are ubiquitous “beings” which cover the world, even within the landscapes modified by man. We all live in a world made of landforms. Sometimes, they seem to us perennial from the dawns of history as effigies of an eternal world, but other times they look so fresh and young, mobilizing sediments, with versatile configurations. The past and the present come together into the same landform; the evolution and the landscape metamorphosis proceed gradually but the rhythm of change is very different, often incredibly slow surviving to our lives or even to existence of mankind while here and there a “whole” world vanish in a few minutes. All these perceptions that senses bring to us define our imagination and finally build our perspective about the world. Happily the man travels all over wondering how the Earth and landforms exist!

This book tries to present the beautiful and awe-inspiring range of landscape features from the glaciers and their action upon high massifs to coastal dunes or subaqueous landforms of the shoreface. This volume is about the diverse landforms of a country where various environments adjoin. Nevertheless, the laws which govern the way which landforms evolve are the same world-wide, but the infinite influences of the modelling agents create always individual features which remain unique as the human face. Moreover, large-scale landscapes as the Danube Delta or Retezat Massif could look very different from any other delta or mountain so that the understanding of their evolution more than applying general geomorphological principles requires site-specific processes research or even to conceive new research methods.

This volume contains a series of new studies grouped in eight parts mainly depending on the geographical environment.

Part I resumes the most recent knowledge and interpretations of the Romanian Carpathians formation and explains the presence of the large morpho-structural units (Maţenco), whereas their sub-aerial shaping can be more readily understood following the reconstructions of climate conditions (Perşoiu) and vegetation distribution in the last 15,000 years (Feurdean and Tanţău) covering the geographical area of Romania.

Part II brings the newest data and interpretations in the field of glacial and periglacial modelling of the Romanian Carpathians, from the history of deglaciation in the Carpathians (Popescu et al.) to the distribution and characteristics of mountain permafrost (Popescu et al.), the review of knowledge on periglacial processes and deposits (Onaca et al.), thermal weathering of mountain rock slopes (Vasile and Vespremeanu-Stroe) and the morphometrical analysis of glacial cirques (Mîndrescu and Evans). The complex evaluation of glacial and periglacial geomorphosites (Comănescu and Nedelea) closes the part dedicated to mountain geomorphology in this volume.

Part III is dedicated to mass movement processes, with the main focus on landslides. The Romanian contributions to the systematic of mass movements is critically reviewed (Micu), completed by detailed approaches and high-technology inventory and informatics processing of landslides for two different geographical areas (the Moldavian Plateau—Mărgărint and Niculiță; and the Curvature Subcarpathians—Micu) and for debris flow activity in mountain areas (Pop et al.).

Part IV, dealing with soil erosion, combines the researches of agronomists on sheet and rill erosion (monitored for 12 years on experimental plots—Popa) with the ones of geomorphologists in gully erosion rates' assessments (Rădoane and Rădoane) and with the progresses made in the mathematical modelling of soil erosion (Patriche). The applications are set in one of the most highly degraded regions of Romania—the Moldavian Plateau.

Part V (Rivers) discusses fluvial landforms and processes in relation to the time required for essential changes to take place: longitudinal profiles which modify their shape during millions of years with implications in relief evolution (Rădoane et al.); rivers behaviour and the formation of sedimentary complexes of floodplains during the transition from Pleniglacial to Late Glacial (Perşoiu et al.); Holocene fluvial activity highlighting the large floods and their implications in the sedimentary architecture and the formation of river terraces (Perşoiu and Rădoane); adaptation of riverbeds' shape (planform and cross-section) to climate changes and human interventions during the last 150, 100 and 50 years (Rădoane et al.).

Part VI deals with the evolution and present dynamics of the Danube Delta and the Romanian Black Sea coast. A new vision on the formation and the evolution of the Danube Delta is presented, in the light of the newest data gathered by the authors (Vespremeanu-Stroe et al.). Distinct sections are dedicated to coastline evolution during the last 150 years (Vespremeanu-Stroe et al.), cliffs retreat on the southern Romanian coast (Constantinescu) and medium-term (decadal) morphodynamics of the coastal foredunes (Preoteasa and Vespremeanu-Stroe) and deltaic shoreface (Tătui and Vespremeanu-Stroe).

Part VII presents the problem of sediment route in various geomorphologic systems. The succession of erosion–transport–sedimentation geomorphological processes is the key for understanding of sediment transport from the source area (Dumitriu et al.) towards riverbeds (Rădoane et al.). Loess accumulation in the Romanian Plain and Dobrogea (Timar-Gabor et al.) and of fine sediments in small mountain lakes (Mîndrescu et al.) have been used to refine high-resolution chronologies and to reconstruct palaeoenvironment conditions at the time of these sediments deposition.

Part VIII (Geomorphologic hazards) closes the volume discussing those climatic, hydrologic and geomorphologic processes capable of generating geomorphologic hazards and disasters: snow avalanches—Voiculescu; mass movements—Micu et al.; river floods—Grecu et al.; coastal storms—Zăinescu and Vespremeanu-Stroe. These analyses prove and highlight the necessity of estimating, on a solid basis, the risk associated with these processes, in the benefit of land administration.

Finally, we hope that geoscientists, specialists in environmental planning, practitioners in water and land-use, territorial unit administrators as well as academics will findthis volume valuable concerning the landform dynamics and evolution and necessary for future prediction of landscape changes.

Suceava, Romania — Maria Rădoane
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Chapter 1
Introduction

Maria Rădoane and Alfred Vespremeanu-Stroe

Abstract The central themes of this volume are the dynamics and evolution of Romania's relief. The two aforementioned conceptual frameworks resulted from the different ways in which time was approached in geomorphology: the 'short timeframe' during which landforms change to a small extent; the 'long timeframe' required for 'historical' transformations of the relief. Time scales of interest in this volume range from the shorter time frame (for the more intensive change rate of the landforms—i.e. soil erosion on experimental plots, debris flow, avalanches) to the largest temporal scales (for the glacial landforms, floodplains or longitudinal profiles). The area of interest for the analysis of the dynamics and evolution of landforms in Romania includes landforms ranging between the 4th and the 9th order. Landform assemblages were approached mainly according to genetic criteria (i.e. glacial, periglacial, denudational, coastal and fluvial).

Keywords Time scales · Space scales · Dynamics · Evolution · Romanian geomorphology

The Framework of Current Approaches in Geomorphology

Throughout the history of modern Romanian geomorphology (Ichim and Posea 1993), three landmark contributions were recognised by the scientific community as highly valuable. The earliest work was '*Realizări în Geografia României*' (Progresses in the Romanian Geography 1973). Despite the wide and comprehensive title, the book deals mostly with the Romanian relief. The contributors

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approach—centred principally upon (establishing) the age and genesis—tackled various topics of Romanian relief from features such as peneplains to the evolution of hydrographical network, piedmonts and depressions, glacial and periglacial relief. Shortly after, it published the *Relieful României* (Relief of Romania, Posea et al. 1974), an essential and original synthesis of genetic geomorphology which reassesses the main topics of Romania geomorphology. The third work, *Geografia României* (Geography of Romania 1983, 1987, 1992, 2005) consists of four volumes where 23 authors reviewed the relief of the Romanian territory particularly from the perspective of the palaeo-geomorphological evolution of landforms and ranked them into several morphostructure-influenced patterns.

The three aforementioned seminal works tackled the topic of relief transformation through the contribution of geomorphic processes tangentially, without discussing quantitative approaches of the geomorphic event rates. About 40 years later, this volume, '*Landform Dynamics and Evolution in Romania*' proposes a different perspective mainly focused on two central themes: *processes* (*dynamics*) and *evolution*.

In order to motivate these two standpoints in approaching landforms, a brief foray into the history of geomorphological thought is required, which will further substantiate the theoretical context in which the two seemingly complementary concepts were defined. For the role of the dynamics and evolution concepts in geomorphology, we retrospect to the landmark work *Dynamic Basis of Geomorphology* published by Arthur Strahler in 1952. For the first time, the theories of process-based geomorphology are introduced in order to explain the diversity of landforms, and what ensued was described by Roads (2006) as follows: '*As a science, geomorphology has flourished since the turn toward the dynamic basis of geomorphology advocated by* Strahler (1952). *This approach treats geomorphological processes and process-form interactions as manifestations of mechanical stresses and strains acting on earth materials*'.

This perspective on the relief soon became the new brand of geomorphological investigation throughout the international scientific community, and the Romanian geomorphology managed at least in part (despite the limitations of foreign scientific exchanges during the communist era) to remain connected to novel trends.

Specifically, the two aforementioned conceptual frameworks (i.e. dynamics and evolution) resulted from the different ways in which time was approached in geomorphology. In one of the finest geomorphological treatises published by Chorley et al. (1984), the basic conceptual elements were drafted and were later resumed by Ichim et al. (1989) as follows:

(i) the *dynamics of geomorphological processes*, where investigation focuses on the role of various processes in transferring sediments, which in turn affect landforms, i.e. the *functional approach* to the study of relief;
(ii) the *evolution*, where investigation centres around deciphering the main stages of change in landform characteristics under the control of major temporal events (sea-level fluctuations, tectonics, climate changes), i.e. the historical approach to geomorphology;

Historicism and functionalism in geomorphology are based on the 'dual character of time', namely either the 'long timeframe' required for 'historical' transformations of the relief, or the 'short timeframe' during which landforms change to a small extent. During the 'short timeframe', the functional approach is applied to those landforms which clearly show the effects of current processes (e.g. gullies, river reaches, hillslopes, etc.), whereas the 'long time', historicist approach is reserved for landforms whose evolution was slow and provide evidence of the climatic and tectonic influences to which they were subjected (e.g. longitudinal profiles of rivers, floodplains and their respective deposits, piedmonts, mountain ranges, etc.). The time scales according to which the dynamics and evolution of landforms can be interpreted are those defined by Schumm and Lichty (1965): cyclic time ($\sim 10^{5++}$ years); dynamic equilibrium or graded time ($\sim 10^{2+}$ years); stationary time ($\sim 10^{-1}$ years), which were reformulated by Hickin (1983) as geologic, geomorphic and engineering timeframes.

In summary, most geomorphological topics of interest (such as the ones tackled in the present volume) require the use of both the *functionalist*, prediction-oriented approach (deduced from the cause-effect relation), and the *historicist* approach aimed at retrodiction/postdiction. The validity of results yielded by our work was verified based on the accumulation of significant amounts of field (in terms of study area, number of cases, measurement period) and lab data. Based on these, the work hypotheses were tested and conclusions were formulated, many of which had a predictive nature. Special attention was granted to the pressure of global changes and human activity (which are rather difficult to set apart) as controls of landform change intensity. Moreover, the new paradigm gaining ground at a fast pace in the worldwide understanding of geomorphology is related to the manner in which hydrological and sediment cycles are manipulated by unprecedented human intervention (Church 2010).

Temporal and Spatial Scales of the Geomorphological Processes Herein Approached

The matter of knowledge transfer between systems of different magnitude is one of the leading topics in geomorphology and is linked to the temporal and spatial scales (Church 2010). In other words, the geomorphological landscape has distinct properties at differing scales of investigation. Each hierarchic level includes the cumulative effects of lower levels.

In order to frame the investigated geomorphological phenomena within temporal and spatial boundaries, we created the graphic shown in Fig. 1.1, displaying the temporal and spatial scales of interest.

Relative to the *time scale*, the shorter the time frame, the more intensive is the change rate of the landform; this is illustrated by soil erosion on experimental plots where the time required can amount to just minutes (Chap. 15), aeolian

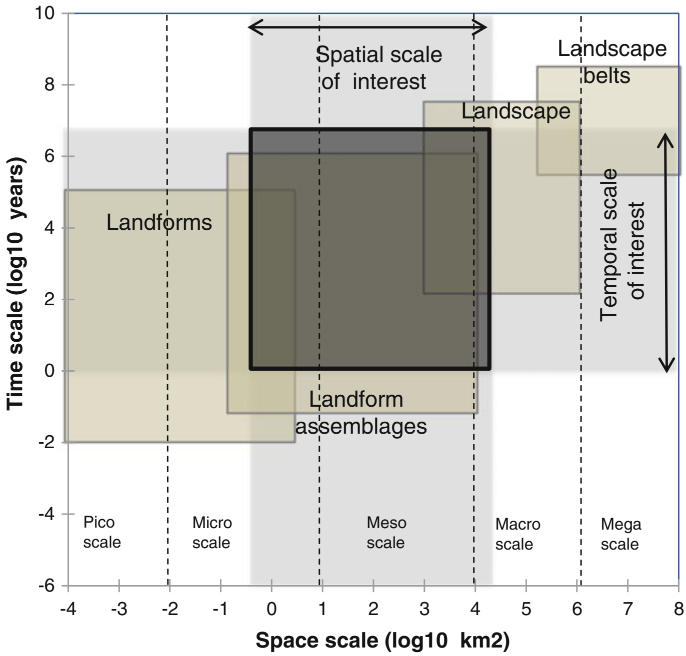

Fig. 1.1 Spatial and temporal scales in geomorphology. In *black* is shown the interest area of researches in the present volume (an adaptation after Slaymaker et al. 2009). Other discussions in the text

micro-features (Chap. 25) or snow avalanches (Chap. 31). Hour-long to day-long time frames are required for the formation of rills (Chap. 15) and sand dunes (Chap. 25) or for debris flows (Chap. 14).

However, the majority of landforms analysed in this volume have change rates ranging from years to hundreds of years, as is the case of hillslopes, river channels (where the rate of channel adjustment was 150 years) or coastal systems. Other processes, such as river channel behaviour and floodplain formation (Chaps. 19 and 20), the genesis and evolution of the Danube Delta (Chap. 22) or lacustrine sediment-inferred palaeoenvironmental processes (Chap. 30), were reconstructed at larger temporal scales (e.g. from 10 to 15,000 years). The largest temporal scales were employed for the analysis of glacial processes (Chap. 5), as well as for modelling the shape of longitudinal profiles whereby the time frame was as ample as 14–15 million years (Chap. 18) in our case.

Relief is a ‘continuum’, and identifying a suitable *time scale* for its genetic and functional assessment is of utmost necessity. The hierarchy proposed by Chorley et al. (1984) (Table 1.1) is eloquent in this respect.

Such a hierarchy is helpful in attempting to differentiate between distinct conceptual frameworks and highlight certain processes and evolutions. Specifically, the area of interest for the analysis of the dynamics and evolution of landforms in

Table 1.1 Spatial hierarchy of landforms (Chorley et al. 1984). The box frame delineates the area of interest for this volume

Order	Examples
1st	Continents, oceans, plates, convergences zones, divergence zones
2nd	Physiographic provinces, mountain ranges, massifs, plateaus, lowlands, accumulative plains, tectonic depressions (morphostructural units)
3rd	Medium – scale geomorphological units, such as folded mountains, faults blocks, domes and volcanoes
4th	Large-scale erosional/depositional units, such a large valleys, deltas and long continuous beaches
5th	Medium-scale erosional/depositional units; smaller valleys, floodplains, alluvial fans, cirques, moraines
6th	Small-scale erosional/depositional units; small valleys, offshore bars, sand dunes
7th	Hillslopes, reaches of stream channel
8th	Slope and flat facets, pools, riffles, gullies
9th	Stream bed and aeolian sand ripples, slope terracettes
10th	Microroughness represented by the diameter of individual pebbles or sand grains

Romania includes landforms ranging between the 4th and the 9th order. Furthermore, in Fig. 1.1 whereby the spatial scale is measured in square kilometres, we indicated the assemblages of landforms as the area of major interest. Landform assemblages were approached mainly according to genetic criteria (i.e. glacial, periglacial, denudational, fluvial). Whereas in most of these categories the meso-scale was selected as area of interest, in some instances the micro-scales (e.g. erosion plots with areas in the range of square metres) or macro-scales (such as mountain units or drainage basins exceeding 10,000 km^2) were also investigated.

Landmarks in the Development of Modern Romanian Geomorphology

One of the most concise analyses of the evolution of geomorphology in Romania was published by Ichim and Posea (1993) in the referential work edited by Walker and Grabau, *The Evolution of Geomorphology*, which provides a number of valuable ideas. The first and most important regards the fact that Romanian geomorphology was part of the regionalist movement/current. Thus, without disregarding the value of resulting contributions, the input to the general theory of landforms was rather understated. The second idea referred to the synchronicity manifested in applying theoretical concepts highly recognised worldwide, albeit for a long period of time (i.e. the communist era) the scientific exchanges with the international community were restricted.

Whereas we do not aim at carrying out an extensive overview of the history of geomorphological ideas in Romania, it is nevertheless worthwhile highlighting important moments which, in our opinion, marked a change in the knowledge, research methods or the interpretation of landforms, in order to gain a better perspective on the work we set out to accomplish and to find another way of approaching the relief. Therefore, we summarised the landmark moments, ideas and personalities which made a significant contribution to the advancement of modern geomorphology in Romania against the time scale (Fig. 1.2).

Fig. 1.2 Timeline of the developments made by the modern Romanian geomorphology during the last 100 years (1915–2015). The two fundamental conceptual frameworks utilised in geomorphological analysis, i.e. historicist (derived from the Davisian theory of landform evolution) and functionalist (focused on understanding processes and mechanism underlying relief dynamics) are delineated

Modern Romanian geomorphology was established, in our opinion, with the work of Vâlsan (1885–1935), *Câmpia Română* (1915) (The Romanian Plain), the earliest geomorphological investigation of a landform from a genetic standpoint. The author conducted geomorphological analysis in order to identify the role of neotectonic movements and outlined the relation between endogenous and exogenous factors. The period was propitious for personalities who established themselves as important figures in the evolution of landforms knowledge: Brătescu (1884–1947), who published studies on sea-level oscillations, loess and asymmetry of fluvial valleys; David (1886–1954), known for highlighting the role of the geological control on morphogenesis, as well as for applying the denudation surface theory in the Carpathians and last, but not least, for his benchmark work in the Subcarpathians; Mihăilescu (1890–1976), reputed for introducing the monograph concept in the study of relief and the first comprehensive classification of mass movement processes, and for publishing the earliest synthesis of landform units in Romania in 1946 (Mihăilescu 1946); Morariu (1905–1982), who investigated denudation surfaces and glaciation in Rodna Mountains. We can further add to the list scientists who also activated during this period and continued throughout the recent decades: Popp (1908–1993), who produced an exemplary work on morphological profiles in the Subcarpathians; Tufescu (1908–2000), who published the first Romanian treatise of dynamic geomorphology (Tufescu 1966).

In the years following WWII, Romanian geomorphology went through two distinct phases:

(i) the reorganisation of research and the elaboration of the first comprehensive synthesis on the Romanian relief, in *Monografia geografică a României* (1960) (the Geographical Monograph of Romania);
(ii) the transition to the systemic research of landforms whereby numerous, very valuable geomorphological monographs investigating landform units, valleys or drainage basins (1963–1990).

The first national geomorphological map (sc. 1:1,000,000, Coteţ 1960), as well as the map of geomorphological regions (Martiniuc 1960) were included in *Monografia geografică.* At this stage, the earliest attempts at quantitative and experimental geomorphological approaches were made, particularly at 'Stejarul' Research Station from Pângăraţi founded by 'Al. I. Cuza' University from Iaşi (1957), the Pătârlagele Geographical Station (1969) pertaining to the Institute of Geography, and the Central Station for Soil Erosion Control from Perieni founded by the Agricultural and Forestry Academy (1954).

From the 1980s onwards, but especially after the 1990s, the interest of Romanian geomorphologists clearly shifted towards the dynamic and applied (functionalist) side of geomorphology, which was also required by the economic development of the country (e.g. large projects for dam construction throughout drainage systems demanded substantial contributions from dynamic and applied geomorphology). It was a period when Romanian geomorphologists created communication bridges with engineering sciences from the need to engage more effectively in solving problems related to land use, resource exploitation, environmental planning and management. A model of pragmatic mixture of geomorphological and engineering approach styles was provided by the book 'The River Channel Morphology and Dynamics' (Ichim et al. 1989), where a team of geomorphologists and hydraulics engineers have complemented each other in the fluvial knowledge domain. The new orientations involved other work styles for geomorphologists. If the pre-1970 period was the one dominated mostly by individual personalities (highlighted in Fig. 1.2), thereafter research groups or teams became the rule allowing for major

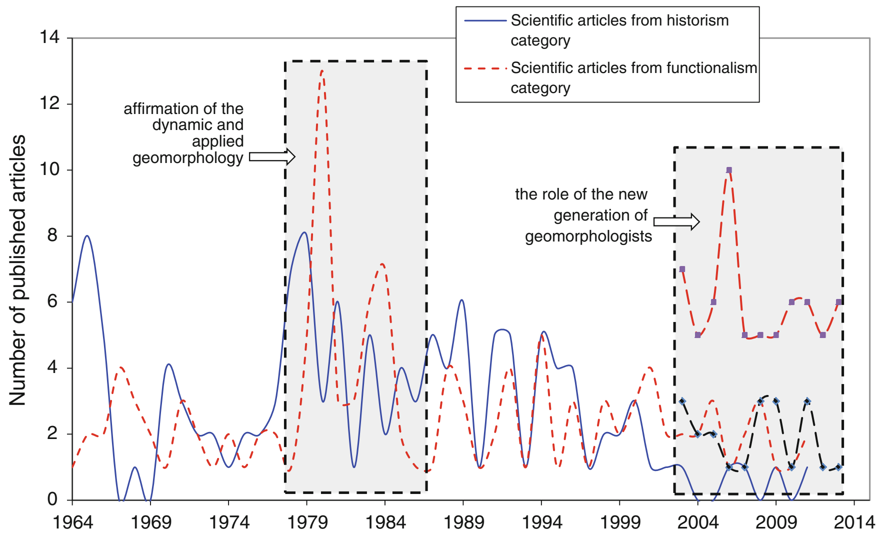

Fig. 1.3 The representativeness of dynamic and historicist geomorphological research according to the number of papers published in *Studii şi cercetări de Geografie, Revue Roumaine de Geographie* (1964–2009) and *Revista de Geomorfologie* (2003–2014)

progresses in many fields, such as the periglacial, fluvial, coastal or sediment dynamics which are all well represented in this volume.

The best evidence in support of these observations is provided by the analysis of the most prestigious Romanian geographical journals prior to 1990 (Revue Roumaine de Geographie—Romanian Journal of Geography, and Studii si Cercetari de Geografie—Studies and Researches in Geography); after the date hereof we also added Revista de Geomorfologie (Journal of Geomorphology). The numbers of scientific articles focusing on landforms from either a historicist or a functionalist perspective were ranked separately for each journal issue (Fig. 1.3). The resulting variation curves are rather self-explanatory in terms of highlighting the conceptual and methodological changes during the 50-year period we monitored. The first observation regards a steady decline in the historicist approach and a significant increase in the interest shown by Romanian geomorphologists to landform adjustments over shorter periods of time. Furthermore, a series of leaps was documented in the variation of the curve, which was outlined in the diagram (Fig. 1.3). For example, the 1978–1988 decade can be regarded as the period of affirmation of dynamic and applied geomorphology, based on the prevalence of articles focusing on such topics; this is the result of the involvement of Romanian geomorphology in tackling a multitude of practical problems, such as land use, resource exploitation and land engineering.

After 1989 (i.e. the year when Romania overthrew the communist political regime), the geomorphology benefitted from the opening and enthusiasm generally manifested during that period (Ichim 1993). The establishment of the Association of

Romanian Geomorphologists in 1990 was an important landmark, albeit previous attempts have been made previously in this regard, in 1972 and 1980 (Posea 1991; Vespremeanu 2005). Throughout this entire period remarkable efforts were made to focus the resources of Romanian geomorphology in order to annually sustain the series of national symposia of geomorphology, now (year 2016) reaching 32 editions.

During the past decades, a new movement synchronous to the worldwide trends in geomorphology became apparent. According to Church (2010), another major leap in the evolution of geomorphology (beginning in the mid-1980s) occurred rapidly post-1990 based on the advancement of technologies employed for landform observation and measurements: '*Dramatic changes have occurred in geomorphology since about 1980, rapidly gathering momentum after about 1990. The bases for these changes are, again, largely technological. The main influences include:* (1) *improved technologies for remote sensing and surveying of Earth's surface;* (2) *the advent of personal computation and of large-scale computation; and* (3) *important developments of absolute dating techniques*'. These technical advancements encouraged two major orientations in geomorphology, namely: opening the way for a renewed consideration of the history of landscape (by reconsidering the role of tectonics in geomorphology) and the ever-increasing degree of recognition of the human factor in the present-day changes of the earth surface. Both research topics have become attractive for the contemporary Romanian geomorphological community (the count of articles published in journals, both Romanian, but most importantly international publications, is yet again proof of this orientation).

Naturally, advancing technologies demand increasingly qualified researchers, of which a large proportion is also oriented towards multidisciplinary. This seems to explain the establishment of several research groups of young geomorphologists (during the past 10–15 years) with education and skills in sciences (geography, physics, mathematics, chemistry, information science) which could successfully implement the novel technologies. This is why within the present volume the contributions of young researchers (<40 years) are prevalent.

Not all branches of geomorphology were equally dynamic throughout time. For example, the hillslope domain retained the interest of Romanian geomorphologists much more frequently prior to 1989 than in recent years (Fig. 1.4). Conversely, other fields of geomorphological investigation (fluvial, coastal, periglacial, Quaternary, soil erosion) underwent remarkable advancements in terms of research methodology, the development of the dynamic and applied side and substantiating conclusions based on processing quantitative data. Furthermore, new fields developed in Romania, such as geomorphometry, boosted by the upgrades in information technology.

We conclude these introductory remarks by observing that the guideline followed in addressing the dynamics and evolution of landforms is related to the concept of geomorphology as system science (Church 2010). As with all environmental sciences (which are essentially system sciences), geomorphology seeks explanations by integrating and superposing the effects of many elements and

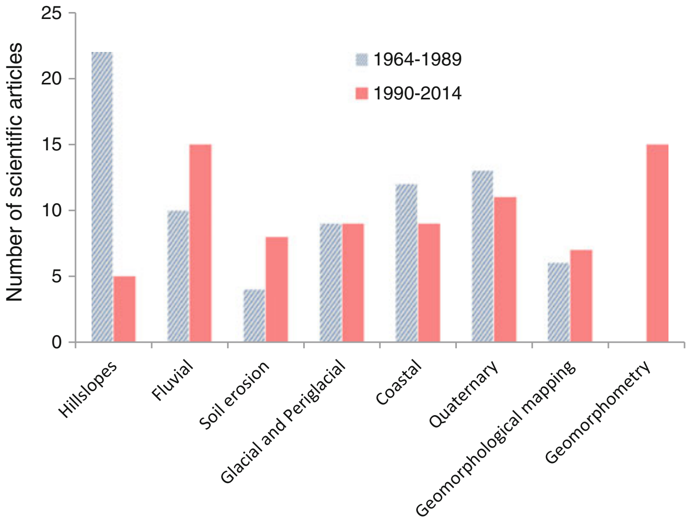

Fig. 1.4 Geomorphological fields covered by articles published in top Romanian journals prior to 1990 and ISI Web of Science journals post-1990

processes acting within a given space during a certain period of time. Thus, in the present volume we demonstrate to a large degree that the central topic—the relief of Romania—is investigated according to thorough concepts and the geomorphological events under scrutiny were analysed based on direct measurements, field experiments, absolute dating and comprehensive databases.

References

Chorley RJ, Schumm SA, Sugden DE (1984) Geomorphology. Methuen, London

Church M (2010) The trajectory of geomorphology. Prog Phys Geogr 34:265

Coteț P (1960) Harta geomorfologică a R.P. Române. In: Monografia geografică a R.P.R., vol. I, Geografia fizică. Editura Academiei Române, București (in Romanian)

Geography of Romania (1983) Geografia Romaniei, vol 1, Editura Academiei Române, București

Geography of Romania (1987) Geografia Romaniei, vol. 3, Editura Academiei Române, București

Geography of Romania (1992) Geografia Romaniei, vol. 4, Editura Academiei Române, București

Geography of Romania (2005) Geografia Romaniei, vol. 5, Editura Academiei Române, București

Hickin EJ (1983) River channel changes: retrospect and prospect. Int Assoc Sedimentol Spec Publ 6:61–83

Ichim I (1993) Geomorfologia in pragul Mileniului III. Terra 25(1–4):83–90

Ichim I, Posea G (1993) Geomorphology in Romania. In: Walker HJ, Grabau WE (eds) The evolution of geomorphology. Wiley, Chichester, pp 363–366

Ichim I, Bătucă D, Rădoane M, Duma D (1989) Morfologia și dinamica albiilor de râu. Editura tehnică, București (in Romanian)

Martiniuc C (1960) Harta regiunilor geomorfologice ale R.P. Române. In: Monografia geografică a R.P.R., vol. I, Geografia fizică. Editura Academiei Române, Bucureşti (in Romanian)

Mihailescu V (1946) Geografia fizică a României (curs litografiat), Universitatea București (in Romanian)
Posea G (1991) Cuvânt inainte. Revista de Geomorfologie 1:1–2 (in Romanian)
Posea G, Popescu N, Ielenicz M (1974) Relieful României. Editura ştiinţifică şi enciclopedică, Bucureşti (in Romanian)
Roads BL (2006) The dynamic basis of geomorphology reenvisioned. Ann Assoc Am Geogr 96 (1):14–30
Schumm SA, Lichty RW (1965) Time, space and causality in geomorphology. Am J Sci 263:110–119
Slaymaker O, Spencer T, Dadson S (2009) Landscape and landscape-scale processes as the unfilled niche in the global environmental change debate: an introduction. In: Slaymaker O, Spencer T, Embleton-Hamann C (eds) Geomorphology and global environmental change. Cambridge University Press, Cambridge, pp 1–36
Strahler AN (1952) Dynamic basis of geomorphology. Geol Soc Am Bull 63(9):23–37
Tufescu V (1966) Modelarea naturală a reliefului și eroziunea accelerată. Editura Academiei RSR (in Romanian)
Vespremeanu E (2005) 40 ani de geomorfologie organizatã în România. Revista de Geomorfologie 7:5–7 (in Romanian)

Part I
Background of Landform Evolution

Chapter 2
Tectonics and Exhumation of Romanian Carpathians: Inferences from Kinematic and Thermochronological Studies

Liviu Maţenco

Abstract The ultimate topographic expression of intra-continental mountain chains is established during continental collision. The Romanian Carpathians provide a key location for understanding the mechanics of collision during slab retreat because the nappe stacking was not overprinted by back-arc extension, as commonly observed elsewhere. A review of existing kinematic and low-temperature thermochronological data infers that the collisional mechanics is significantly different when compared with high-convergence orogens. The shortening of the orogen at exterior was entirely accommodated by back-arc extension and the area in between simply rotated and moved into the Carpathians embayment. The roll-back collision is driven by foreland-coupling, a process that gradually accretes and exhumes continental material towards the foreland. The topographic expression of the Romanian Carpathians is both inherited from latest Cretaceous—Paleogene times, such as in the Apuseni Mountains or South Carpathians, and overprinted by the Miocene exhumation associated with the roll-back collision, as in the East or the SE Carpathians. The migration of exhumation towards the foreland continued during Pliocene—Quaternary times and is still active modifying the present-day topography in the SE Carpathians. The Transylvanian Basin is one of the best examples available of vertical movements induced by deep mantle processes in what is commonly referred as dynamic topography.

Keywords Kinematics · Thermochronology · Exhumation · Carpathians · Orogenic mechanics

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Introduction

The kinematics and exhumation of collisional orogens have been a constant topic of tectonic studies since the definition of steady-state wedges and associated large-scale hinterland exhumation during the buoyant subduction of continental plates (e.g. Platt 1986; Beaumont et al. 1994; Ring et al. 1999). Continental collision is the moment when out-of-sequence contractional deformation becomes rather the rule than the exception. Understanding its importance is fundamental for a fairy large number of orogenic processes, such as emplacement of metamorphic nappes, exhumation of high pressure rocks, deformation of thin-skinned thrust belts, the interplay between shortening and surface processes, syn-orogenic extension, the geometry of foredeep basins or accretion of continental material (e.g. Marotta et al. 1998; Burov 2007; Doglioni et al. 2007; Burov and Yamato 2008; Haq and Davis 2008; Naylor and Sinclair 2008; Faccenda et al. 2009). When compared with the strain partitioning observed during oceanic subduction stages, the out-of-sequence collision deforms a much wider zone, compressional stresses being transmitted much farther in the orogenic foreland and hinterland (e.g. Ziegler et al. 1998; Roure 2008).

The kinematics, geometry and exhumation of European orogens can be simply divided in two main categories (Fig. 2.1).

High-convergence collisional orogens, such as the Pyrenees or the Alps are characterized by large amounts of contractional exhumation. This exhumation is enhanced in orogenic hinterlands along retro-wedges that display a complex poly-phase deformation with an opposite polarity when compared to the one of the subduction zone (such as the Insubric line, Roure et al. 1989; Schmid et al. 1996; Beaumont et al. 2000). On the contrary, the "Mediterranean"-type of collisional orogens is dominated by subduction processes, resulting in the formation of highly arcuated mountain belts, such as the Apennines, Carpathians, Hellenides and the Betics–Rif system (Fig. 2.1). These orogens evolved rapidly during the retreat (or roll-back) of genetically associated slabs (i.e. Calabrian, Vrancea, Aegean and Gibraltar, respectively) that peaked in almost all situations during Miocene times (e.g. Jolivet and Faccenna 2000; Faccenna et al. 2004; van Hinsbergen et al. 2005; Ismail-Zadeh et al. 2012; Vergés and Fernàndez 2012). The slab retreat is accommodated by coeval extension affecting the hinterland of the upper orogenic plate, which formed large basins floored by either continental or oceanic lithosphere (such as the Pannonian and Aegean Basins, Black Sea or Western Mediterranean). These basins are extensional back-arcs in terms of geodynamic evolution (e.g. Royden 1993; Okay et al. 1994; Jolivet and Faccenna 2000; Horváth et al. 2006; Doglioni et al. 2007) although their relative position behind a magmatic or island-arc (Uyeda and Kanamori 1979; Dewey 1980; Mathisen and Vondra 1983) is not always very clear. In almost all situations, the back-arc extension overprinted and hid the earlier continental accretion, in particular by exhumation along extensional detachments, such as the widely documented core complexes of the

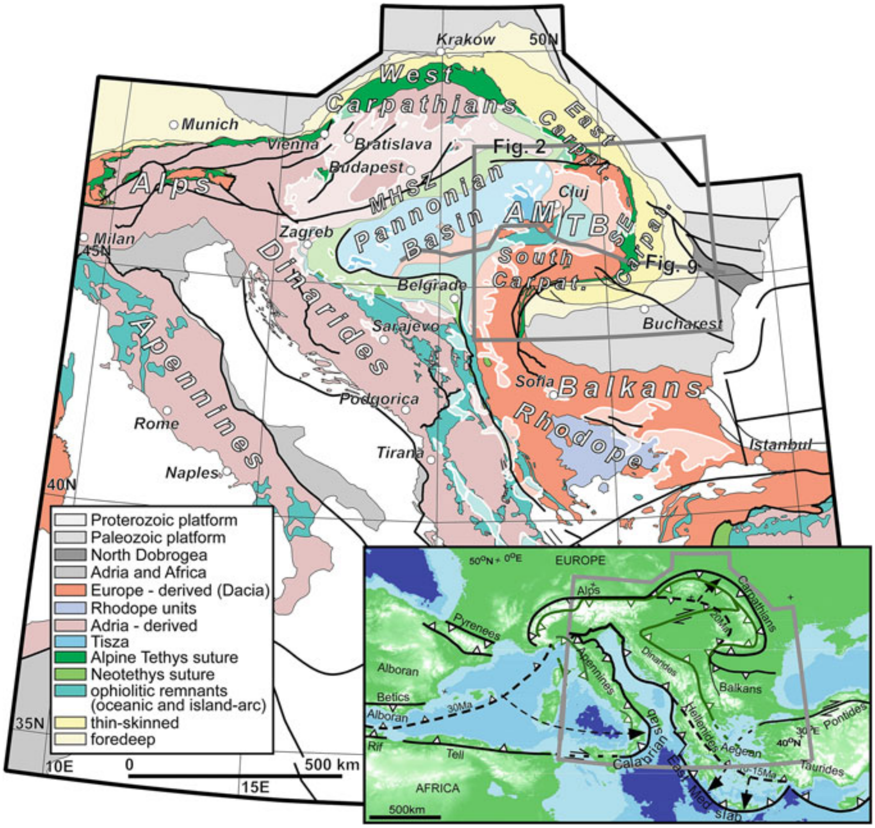

Fig. 2.1 Tectonic map of the Alps–Carpathians–Dinaridic–Hellenidic system (simplified from Schmid et al. 2011) with the extent of the Pannonian and Transylvanian back-arc basins (white transparent background). The *grey rectangle* is the location of Fig. 2.2 *AM*—Apuseni Mountains; *TB*—Transylvanian Basin; *MHSZ*—Mid-Hungarian Shear Zone. The lower inset is the location of the map in the system of European Mesozoic—Cenozoic orogens. *Dashed black line* is the position of the orogenic front prior to the onset of extension associated with the roll-back of the Calabrian, Aegean and Carpathian slabs

Rhodope–Aegean or Betics (Brun and Faccenna 2008; Brun and Sokoutis 2010; Vissers 2012).

An exception is the Romanian segment of the Carpathian Mountains, where the back-arc extension associated with the retreat of a slab kinematically connected with the stable European foreland (e.g. Schmid et al. 2008) took place during Miocene times in the Pannonian Basin, i.e. at far distances from the active subduction. This Miocene extension is rather minor in the areas situated in between, i.e. the eastern Apuseni Mountains, Transylvanian Basin or the East, SE and South Carpathians (e.g. Tiliţă et al. 2013). The clockwise rotation and E-ward translation of these Carpathian units accompanied the W-ward subduction of the Carpathian