BABES-BOLYAI UNIVERSITY
FACULTY OF GEOGRAPHY,
PHYSICAL AND TECHNICAL GEOGRAPHY DEPARTMENT

PHD THESIS

GEOMORPHOLOGICAL DETERMINATION FOR URBAN DEVELOPMENT OF CHISINAU CITY

SUMMARY

SCIENTIFIC ADVISOR:
PH.D. PROFESSOR VIRGIL SURDEANU

PH.D.:
MARIANA OLEINIC

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CONTENT

RESEARCH CONCEPTUAL BASES

Topicality. Applied urban Geomorphology study of Chisinau city it's a necessary one, concerning territorial planning in the context of Moldavian capital sustainable development. Urban relief study became a current concern which drew attention in a particular way being the key of a complex geographical research based on field investigations. In present, Chisinau city evolution is constrained by little ground substance (2,1 %) for territorial expansion, which requires morphological support and its morphodynamics on which the city develops. Permanent transformation of geomorphological landscape from hearth and outside city built over areas in urban purposes resulted in areas of different vulnerability which requires monitoring and territorial management according to relief suitability.

Situation description in research area and identifying research problems.

In Moldavia Republic there have been concerns regarding natural environment study of rural and urban settlements yet from 19th century (1813-1823) when they did the first topographical survey regarding Chisinau planning and urban systematization. After World War II, during the years '60-'80, these types of research spread. In this respect A. Levadniuc promoter of applied geomorphology founded a prestigious group of researchers (A. Gherasi, Gh. Cernov, L. Ignatiev etc.) within the Geography institute. Together they developed many applied geomorphology studies using aerials and several types of maps (slopes map, relief energy, drainage density, hypsometrical, geomorphological etc.) In the same period (1988), S. Orlov and T. Ustinova have accomplished geomorphological studies in order to solve the problems related to morphodynamics and slopes vulnerability from Chisinau urban space.

Also, within AGEOM, V. Tcaci and his collaborators performed and continue today several researches on the slide processes evolution and on the linear erosion inside Chisinau boundaries. Affected lands were delimited and they monitored every landslide for evaluation and recommendation for these capitalization perspectives. Also at this time Capcelea and collaborators are noticed through anthrophogenic factors research and their impact in terms of urban areas (Chisinau, Balti, Bender etc.)

Although Chisinau the country's capital with all sizes and functions performed regarding physico geographical and socio economic landscape at the country level, in terms of geomorphological was not sufficiently researched. Undertaken studies had a general view reffering to the morphology and morphodynamics of Central Moldavian Plateau (Poruciuc, 1929; Drumea, 1964; Orlov, Ustinova 1969; Proca, 1970; Bilinchis, 1978; Levadniuc, 1983 etc.). Also for urban areas morphological investigations are too general (Constantinova T., Sardoev and collab., 1993; Capcelea, 2001) or rather limited (Drumea 1963; Fedorcenco, 1974; Tcaci and collab., 1981; Orlov, 1982; 1984; 1988) targeting the current morphological processes in particular with pronounced morphodynamics –landslides. With a direct and broader vision only *Kisiniev: Acologo-gheograficeschie problema* (Constantinova T. and collab., 1993) paper work is being noticed. Currently within Geography Institute, collaborators N. Boboc; Gh. Sârodoev; A. Gherasi, L. Ignatiev and others elaborate studies on optimal management and sustainable development within the built up area space. Therefore poor applied geomorphology works in Moldavia Republic especially regarding urban settlements increases the importance of this study. In this context should be mentioned that Chisinau city has served as a complex geographic research subject supporting specialist designers regarding a sustainable capital development.

Study's purpose consists of establishing and studying geographic favourable factors (climatic, hydrological, pedological) and restrictive factors (petrography and relief) in Chisinau's city development process and identification of relief suitability regarding territorial expansion.

Main Objectives are:

- establishing knowledge methodological principles in general and those of applied geomorphology in particular ;
- assessment and characterization of factors favoring the process of urbanization;
- territory lithology analysis prevalent friable that shows vulnerability to moisten, earthquake, overload construction;
- quantitative and qualitative analysis of urban landscape in the context of Chisinau sustainable development;
- identification of relief active dynamic elements indicating current modeling processes;
- highlighting areas of geomorphological vulnerability and suitable relief areas concerning urban evolution.

Scientific Research Methodology for this study was based on a number of principles and methods: space distribution principle, distribution in time principle, integration principle, causality principle, sequence principle, anthropic principle, cartographic method, dismissive relief analysis method, overlay thematic map method, microscaling geomorphological analysis method, morphographical, descriptive methods. Methodological arsenal has been completed by GIS techniques which have proved to be very useful in combination with some of the methods listed above.

Scientific novelty and originality:

- it has determined that Chisinau urban development is favored by biopedoclymatic bases, while the relief is subject to a “stress” that occurs in the territory through disturbances and geomorphic risks;

- it has been demonstrated that in the city sustainable development process the relief plays a major role which is justified and supported by cartographic material developed;

- geomorphological framework in which the city develops has been mapped emphasizing high, medium and low suitability areas given by the territory morphology and morphodynamics. Optimal suggestions have been proposed concerning urban evolution (in present) avoiding geomorphological risk situations.

- for Chisinau city a study of urban applied geomorphology has been made, used by designers specialists will allow locality sustainable development in relation to topography.

Theoretical significance

- theoretical and methodological aspect of studying urban applied geomorphology are explored.

- regarding territorial expansion and sustainability of the town, bibliographic, statistic, mapping and archieves information are evaluated.

- this work is based on field investigation results and on literature sources which aimed at highlighting the *current trends*, the *real ones* and the *prospects of urban development* in relation to the landscape.

Paper work applied value:

This study is useful in Chisinau’s planning and urban development process, where detailed knowledge of topography and potential morphodynamic allows optimal exploitation of the territory. This paper comes to the aid of specialists planners supporting their applied targets on sloping land forms, offering them morphometric and morphographical data about the slope of the urban and peri-urban area limits, natural and real possibilities. Cartographic material developed will also facilitate the inventory and selection of land for certain types of construction. Vulnerability maps and urbanization geopotential can be used in determining the prospects of development and territorial expansion of the capital in the context of sustainable development.

Thesis structure

The thesis is structured in introduction, seven chapters, conclusions, four appendices including geomorphological map, bibliography of 118 titles, 68 figures, 18 photos, 5 tables all of which are located in the 189 pages of text.

Key words:

Chisinau, applied urban geomorphology, methodology, territorial extension, favourable and restrictive factors, friable petrography, morphological framework, morphometric data, active morphodynamic, vulnerability, suitability, sustainability.

THESIS CONTENTS

Chapter I, "Principles and methods in urban geomorphological research" presents general issues relating to applied geomorphology. Applied Geomorphology in the first phase of its evolution has completed some studies: soil, technical, development of seaports, the prospecting of deposits, settlements, systematization etc. Subsequently, however, came up with concrete proposals and solutions concerning territorial planning and relief management as a natural resource. Having the morphodynamic and morphogenetic features as a scientific support of the existing topography, *applied geomorphology*, provides evaluation and optimal management of the proposed territory study. Therefore, the outcome of the evaluation confirms researched area regionalization and systematization , taking into account the suitability of the landscape and the proposed target. Naturally, the diversity of applied geomorphology studies have contributed to the affirmation of science, but also led it to conclude new branches, like *engineering geomorphology*.

Objectives

Applied geomorphology	**Engeneering geomorphology**
- examines the landscape as natural resource; - performs regionalization and landscape managemant with different suitability; - deals with space planning and systematizaton as a whole; - provides general solutions for sustainable development and extention directions, etc.	- examnines the landscape as ground foundation and support for different types of urban constructions; - performes local studies depending on both type and size of the buildings; - deals with planning and punctual systematization of the slopes sectors and river meadows; - provides tehnical solutions, protection measures for the relief with a certain degree of vulnerability as well as for the constructions completed and exploited by man;

Thus, it is clear that applied and engineering geomorphology are sciences of analysis and synthesis, which provide technical solutions on the relief optimal use and management of the outside built over area and within the built up area perimeters. In this respect, geomorphologic research is directed primarily into territorial planning and sustainable development of urban settlement. Following the determination propose as complex as possible of the geographical support in the study area, for sustainable development perspective we used a set of principles and general methods. A study in applied geomorphology puts us in front of a complex problem, therefore, it must be done in the power of *methodological principles of knowledge* in general and especially in those of applied geomorphology. The general methodology is guiding the research towards the highlighting of the major points that control, coordinate and complete the formation and evolution of the relief, regardless of time or spatial scale on which we relate to. Under this methodology, known approaches are expressed by principles and concepts. In the category of geographical principles with methodological significance for the conducted study the following fall: the principle of spatial distribution; time division principle; integration principle; causality principle; sequence principle; anthropic principle. These principles have been added applied geomorphology specific methods used separately or in various combinations throughout the study: analysis method, synthesis method, dialectical method, inductive method, deductive method, comparative method.

Among the first methods used in the present study was *geomorphologic al mapping.* Given that is an applied geomorphology study on an urban area, detailed geomorphologic mapping of the entire territory was performed, without any recourse to extrapolation. Also there were used other methods*: relief expeditious analysis method, overlay thematic map method, morphographic, descriptive method*. Methodological arsenal was completed by GIS techniques, which have proved very useful for the study, in conjunction with some of the above listed methods.

Also, this chapter presents a brief history of the geomorphologic researches on urban planning in relation to the landscape.

In Chapter II, " Chisinau territorial evolution trends caused by numerical increase of population and economic development" presents the history of temporal-spatial evolution of Chisinau, caused by increasing number of population and economic development. Chisinau was certified for the first time in a document dated 17 July 1436 in which is mentioned *"Chisinau Selistea on Bacu"* in front of a grove, where they found a tatar settlement (quoted Nistor, 1991). It is Seliste ferry on Bâc shore, where they established several families of peasants who are engaged in animal husbandry and plant cultivation[1]. Bâc Valley will become the main compositional axis of Chisinau, within this framework focusing maximum cargo village. *In the first phase, extension was performed on the right side of the Bâc valley having as geomorphologic support the river meadow and river terraces* (T1-35-40 m, T2-55-60 m). River (today being strait-laced in concrete banks) was then accompanied by swamps and ponds created by windows formed

[1] However, it seems that Chisinau already exists as a small rural settlement on the right bank of Bacului valley already during the reign of Alexandru cel Bun (1399-1432) (Eşanu, 1998).

for the operation of water mills. Swampy areas and slope angle on the left side of the valley have been avoided for a long time.

Easily finds that within the initial stage of development the first people in Chisinau chose the site for the location of the settlement, given the frequency of certain processes and phenomena with negative effects in territory. Sloping and fragmented surfaces were subjected to geomorphological processes and not only, they were rated unsuitable for construction. From here emerges the idea that the site and land selection for expansion was based on "forecast" process, without precise studies on the relief. Thus, the geomorphologic framework limited hearth extension on the left side of the Bacului valley imposing a linear development on its right side. On Chisinau territorial development in time and space we can emphasize four chronological stages, which note the main ideas of urban development in relation to topography:

1. *Previous nineteenth century step* until the early nineteenth century, the city continued to grow only on the right side of the Bâc river (Fig. 2, pag.18, thesis). Subsequently, the territorial development process has outlined a linear direction with a simple texture to the southeast, on the right side of the valley. The houses were located along the main road on the terrace of 35 m and 55 m. Bâc valley asymmetry has long obstructed extending west, north-west and partly to the south.

City development on the site of former village Chisinau was determined by favourable geomorphologic framework extended up from the right side of the valley river meadow, river terraces and gently inclined slopes (5-7 °). Favourability was supported by the Bâc valley neighbourhood, water table near the surface and high fertility soils. Considering these aspects, one can deduce that all geographical elements have been attractive for setting the first houses, which essentially led to the creation and shaping of the *urban settlement*.

2.Nineteenth century step, a period we call *the threshold*, because it records a serious step in transforming the analyzed town from an unsystematized urban settlement in a representative urban center in Eastern Europe. Demographic expansion process resulted in territorial expansion of urban hearth. Thus, Chisinau grow, approaching the surrounding villages: Vovințeni, Buiucani Muncesti, Hrusca, Malina Mare, influencing them positively and preparing them for full incorporation. In 1834, under the aegis of P. Fedorov and his colleagues (quoted by Capcelea, 1998) was prepared the first Urban Plan of Chisinau (PUG). This plan provided planning and regulation of the existing part of the city and exploitation of the vacant land on the left side of the valley. *Under the plan, which founded the city's bilateral development (on both sides of the Bâc* *valley) and hearth elongation on those lines, it was out of the old geomorphological framework, also taking advantage of the gently sloping and fragmented slopes.*

3.*Twentieth century step*, on the development of the village during this period, defines three stages, namely: *wars stage* (1918-1939), *transition stage* (1940-1944), *post-war* stage(1945-1989). Territorial development to the west and northwest *continues to be restricted* by inclined slopes (7-15 °) fragmented by dales, and to south and southwest by the flood plains and marshy areas of Bâc river meadow. At this stage (1945-1989) were rebuilt neighborhoods: Centru and Botanica; and developed other neighborhoods and areas of the city: Râşcani, Ciocani, Buiucani, Munceşti etc.

It is noted that in this unit of time the main focus has been on loading and expansion of the village, so, intense urbanization process has created a series of ecological, geoecological and geomorphological problems. Urban areas process of expansion have a normal level, what was required, however, was the systematization and management of outside built over and within built up areas. As a result, gradually and with difficulty vulnerable slopes sectors were occupied, contributing to the development of new landslides (eg. Buiucani) and reactivation of old stable ones (eg Petricani, Morilor Valley). Also, petrographic condition namely the loess deposits preponderance, strongly involved in urbanization throughout overload slopes favoured destabilization through affaissment and pipping. The need for space and population trends to remain in the original sector led to hearth extension on the left side of Bâc valley where declivity and drainage density were subordinated disadvantages relating to landslides, affaissment and linear erosion etc.

4.The current phase (1990-present), at this stage the numerical increase of population and economic development runs very slowly. Currently, Chisinau is in a fund limited land crisis for expansion. In addition, the extension is made at the expense of built up areas which are predisposed to certain geomorphological risks (eg, Morilor Valley, Petricani, Schinoasa Dale etc.). Works diversity (earthworks, adjustments in the river system, districts systematization etc..), which is made for urban planning, disrupt the natural cycle of evolution and landscape shaping, increasing or decreasing certain morphodynamic processes. The main purpose of the evolution of Chisinau in this step is getting the right urbanization strategies, which aim to ensure sustainable development of the locality.

In chapter III "Biopedoclimatic support features" are analyzed the physico-geographical factors that promote urban development process: climate support, hydric support and edaphic support.

Urban climate refers *to the village hearth on to the out-skirts built space* (Farcas, 1999) and the intensity of climate changes is currently determined in particular by intense anthropic factor. Chisinau's topoclimate edited its parameters, with the replacement of natural morphological support with various construction materials with irregular shapes and radiating caloring properties different from outside built over areas. Non-homogenous microclimate in the hearth of the city is also conditioned by the underlying surface features, of which *relief* plays a major role.

From the main features of the climatic elements atmospheric rainfalls show interest. The average annual precipitation totals value is 513 mm. There is a difference between outside built-over areas and within the built up areas which receives 20-40 mm more rainfalls. Also, slopes with west and nort-west exposure enjoy richer rainfalls, about 20-50 mm more than other slopes.

Annual precipitation amounts recorded multiple variations given by the frontal cyclone and anticyclone circulation in the studied area. Monthly amounts have the highest annual frequency ranging from 100-150 mm and the lowest quantities greater than 150 mm and less than 200 mm. The distribution of rainfalls in a year appears uneven in the warm semester (April-October) falls about ¾ (386 mm) of total precipitation remaining ¼ (127 mm) in the cold semester (November-March). The pluviometric maximum rainfall is recorded in June but there are deviations because it can be moved in any other month. Pluviometric minimum (29 mm) recorded in 1993, on March, is due to the high frequency of the continental air in the winter months (Fig. 1).

Thermal regime has a negligible influence on the current morphological condition and on its morphodynamics, the pluviometric rainfall regime having the main role. In this respect, release and landslides evolution are directly related to the amount of precipitation and their seasonal distribution. Cold period precipitations often fall as rain. Cold period precipitations often fall as rain. On Chisinau territory 8% of precipitations fall as snow, 81% as rain and 11% are mixed precipitations (rain and mixed precipitation exceeding 90%).

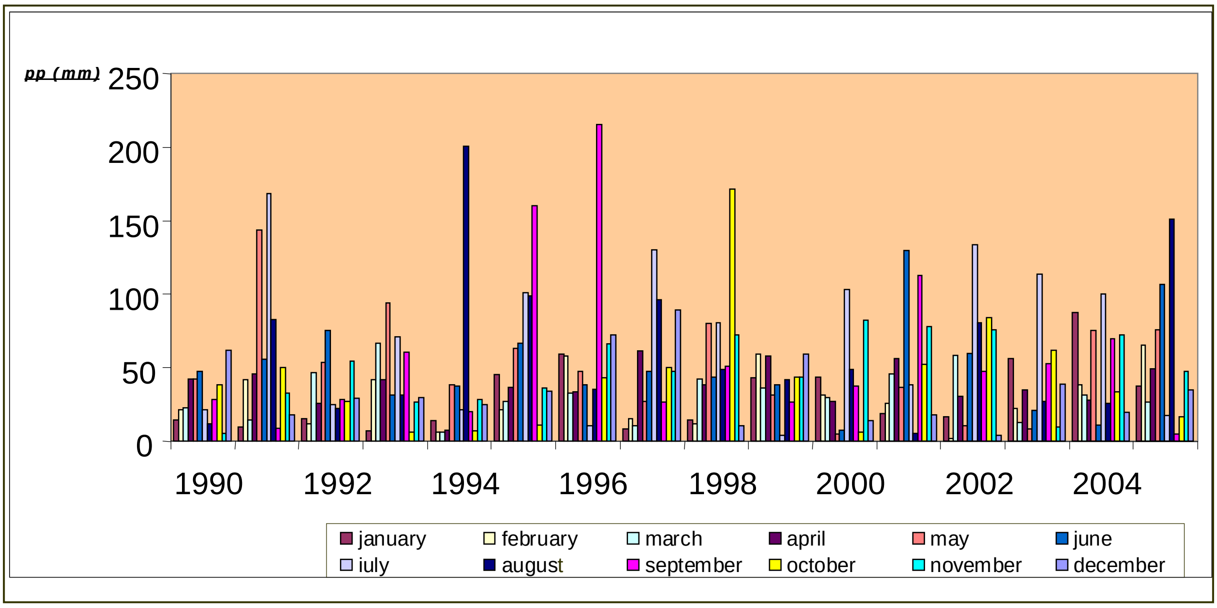


Fig. 1 Annual repartition of precipitations for the 1990-2005 period

It is noted that precipitations fallen on the investigated area do not directly influence the slip processes. Therefore, existing landslides in slope areas and reactivation of others is directly related to certain times of the year (spring, autumn), which attests supersaturated slope deposits with rainfall and water resulting from melting snow.

Carefully analyzing the data in Fig. 1 and on the *"Inventory of landslides"*, we find that there is a correlation between landslides and precipitation during autumn. For example, in the autumn years 1996, 1998 reactivation of landslides is observed on the right side of the Gastelor dale, Sfanta Vineri dale, right slope of Schinoasa dale (Struguras motel), Uzinelor street, right slope – Petricani road, all conditioned by the large amount of precipitations (340 mm – 320 mm) and by anthropic actions. Particularities of the main climatic elements (air temperature, precipitations, atmospheric pressure, wind, etc.) and seasons features highlight the climatic support favourability for urban development of Chisinau. The main characteristics of Bâc water flow in Chisinau are determined by its seasonal variations. Note, however, that, near Chisinau flow volume increases on account of the city's wastewater. Torrential character of the water flow rates in Chisinau is determined mainly by atmospheric precipitation torrentiality, energy and landscape fragmentation and inclined slopes deforestation. In predominant lithological friable conditions, easily eroded, the slopes erosion and denudation, the river beds clogging (Bâc, Durlesti) and the creek dales are increasing. For monitoring and assessing the probability of floods (Fig. 10, pag.43, thesis) and high floods, are necessary a series of quantitative data on water flows and volumes of drained water on the riverbed studied. We analyzed the average monthly liquid flow rates (Annex 1, thesis) of the Bâc river, which were subsequently processed on MATHCAD program, compiling the corresponding graphics and histograms (fig.11-15, p. 1945-1948, thesis). In conclusion, the curves obtained show that the multiannual average flow (Qm.m) is 1.569 m^3 / sec and Qi = 4, 8m ^{3} / sec, which corresponds to a frequency of 22.6% and 77.4% correspond to lower flow. This situation is atypical, having in mind that frequently the average flow rate (QM) of a river has a weight of 30-40%. Thus, in these predominantly low-flow conditions, the causes that will contribute to the *occurrence of flooding in the studied area are of* anthropic origin. Therefore, in Chisinau the hydrological factor has favourability in the process of urbanization. Technogenic action of modern man, either positive or negative, causes a soil analysis - a powerful thin layer exploited by intensive agriculture, accelerated urbanization and industrialization and other anthropic activities. As result of these actions the soil has transformed, making it vulnerable even to likely environmental components (Ursu, 1994).

Diversity and *edaphic cover* complex intermittation from the studied area reflects changes/variations, in time and space, of pedologycal process caused by local *geological, geomorphological and bioclimatic conditions* which, in the process of evolution have transformed parent material into current soils. According to the characteristics listed, on the investigated area distinct in particular are the blacksoils class with types and subtypes (normal, levigated, carbonated, typical). There are greysoils (typical and soft) and protosoils (represented by alluvisoils and erodosoils). Also, the main soil types are distributed in the area.

Analyzing soils map (Fig. 16, p. 52, thesis) is found that the most widespread soils in Chisinau are *blacksoils* and on lower surfaces we meet *greysoils* and *protosoils*. Regarding main soil types it is noticed that structured blacksoils class friable with *typical and ordinary chernozem.* They are dark with clearly differentiated profiles, with accumulation of humus, with favorable chemical and biochemical properties, indicating a higher fertility potential. They are widely used in agriculture, especially for the cultivation of cereals and industrial crops. In the western part of the city, free of carbonates and well humificate levigated chernozems occupy insignificant areas. On relatively small areas, located on leveling surfaces rarely on the slopes, greysoils meet, on some slopes sectors; levigated chernozem is noticed on interstream. Sporadically vertisoils meet. In the southeastern part of river Bac meadow are distinguished alluvisoils which belong to halomorfe class (saltiness soils). On the entire studied area degraded soils group is being noticed, *erodisoils* which are affected by erosion processes and landslides. The soil cover within the built up areas differs essentially from natural soil, is heavily polluted, eroded and poor in humus. Alluvisoils from Bâc river meadow and Center district soils are heavily modified. There is an ecological imbalance between "open" and "closed" areas. Due to technological pressure, taking into account the high density of buildings and multitude of paved surfaces, even “open" areas (grassed, wooded areas, parks, etc.) differ significantly from natural soils. Urban anthropic factor heavily capitalized pedological support, which induced soil destabilization from the built area. Therefore, they are removed from the direct interaction with the environment and only minor areas which correspond to the soils of the parks near the lake, Morilor valley, Trandafirilor valley, La Izvoare, Alunelul communicate with the environment. However, the structure of the soil cover has the necessary resources to create good quality green spaces.

Chapter IV “Geological Characteristics” analyses substratum, deposits, the seismic aspect, hydrological and geotechnical properties of the urban teritory. The sarmatiane deposits (volhinian, bessarabian and chersonian) are actively involved in the actual process of relief modeling (figure 20, page 61, thesis).

It is necessary to mention the fact that among the sarmatian formations, the bessarabian deposits present a major interest because they are frequently involved in the process of actual restructuring of the relief of Chisinau county. This fact is confirmed by the majority of slides which are of a flowing type (which involves in the slide in process the bessarabian clay deposits) and also by the plastic bock slides (which develop in clay structured inserted with bessarabian sands). During the pleistocen era the contour of the present hydrographic net (by deepening the river beds and terrace formation) was established together with the modelation of slopes through the process of erosion and sliding and also processes of loessification took place.

In holocen era the actual relief of the urban area was consolidated: the levelling and structural surfaces, the water meadow of Bac river and of its affluents, and temporary and permanent water courses, etc.

By describing the underground of Chisinau county we meant to emphases its evolution process as well as the major role of the geological support made of deposits vulnerably to wet and to overbuilding. Presently, these deposits represent the grounds of foundation/support of the analysed county, a fact that implies taking into consideration a possible risk. In order to present risks in the urban area, one should study the physical and mechanical properties of the rocks which confer a certain resistance or sensitivity to compression and friction.

Within the urban area, the following structures of superficial deposits can be noticed: eluviums, diluviums, colluvials, proluviums and alluvials (figure 21, page 64 thesis). Diluviums are deposits accumulated on slides (influenced by gravitrope forces), sometimes fix, othertimes in movements. The constituent material originates in the superior part of the slopes which creates a difference between the surface deposit and the one from the inferior part. The diluvial structure is of quaternary-superior age and it is found continously on the primary slopes of Bac river as well as on the secondary ones – the slopes of the valleys (in the central and inferior part). In the territory there is a predominance of fine sandy diluviums clay-sandy, relatively homogeneous. The studies on the ground slides (Tcaci, 1983,Orlov et al, 1988) evidenced diluviums with variable thickness: flowing slides 1-3m, for slides in blocks (blocovo-plasticeschie) 6-15m and even more. These deposits cause various problems on the territory of Chisinau because the clay matrix, which represents an important element in the componence of diluviums, retains water. Thus the cohesion being highly reduced, the slopes loose their stability easily, even in case of less deep digging.

For a correct estimation of superficious deposits as foundation grounds, it is necessary to make geotechnical analysis, interdisciplinary studies, based on the dimensions and destination of the buildings. We wont deny the fact that the urban development of the county amplified the building process of various engineering objectives which are normal for an urban area. The problem is that some of these constructions were made in areas which don't correspond from the perspective of the morphology of the area. Because urbanisation is a process of continuous evolution and the building process can't be stopped, it is recommended to find solutions for safe foundations as well as majors of adapting the structure to the ground. Thus, we mention that there is a need of data in order to estimate if a certain piece of land is suitable to be build on, data which is double by geological, hydrogeological, and geomorphological studies. In this respect, a case study is mentioned for a piece of land of over 3 km² situated in the south-eastern part of Botanica neighbor. According to the geotechnical hydrogeological and morphological data, the degree of susceptability and the evolution stage of the sliding processes, the following areas have been identified: **F**-favourable for construction; **MF-**moderately favorable; **NF –** unfavourable for construction (fig. 2).

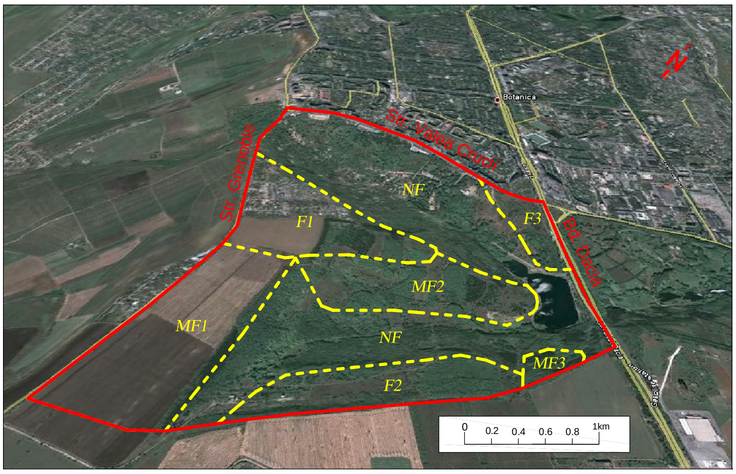


Fig. 2. Suitability partitioning of the territory for urban arrangement

The ***F1*** area is suitable for multilevel building on condition that works are performed before hand, in order to eliminate the factors which can cause sinking. In the ***F2*** area, the aquifer layer is noticed at 5-10m depth. This area is adequate for different types of constructions if a net of draining the residual waters is provided. The ***F3*** area represents an area suitable for building blocks.

The ***MF1*** area is used for agriculture. It is possible to build blocks on this are, but serious preparations against sinking are compulsory. The ***MF2*** area is compatible with house building (P+2), but there is a necessity of engineer work in order to drain the water which will come from downing the water level. The ***MF3*** area occupies the right slope inclined with 5-6 degrees of the right side of the dale, where older slides can be observed. It is possible to build houses (P+1) on condition that a system of rain water capture is build, since it can be billed in the impermeable clay.

The ***NF*** area occupies most of the region (1.8 km²). This area comprises both branches of the dale. At the level of the dale slopes one can notices an accentuated morphodynamics given by different generations of land slides (older or newer). In the perspective of using this area in the process of urban growth, it is recommended to determine the limits of the areas suitable for constructions (7 being already determined) and some work of consolidation is mandatory.

From the seismic point of view, possible damages of the studied area will be registered in the low part of the county (Bac valley and its affluents), a fact due to the land structure, mainly the high waterbed, the presence of alluvial deposits (mud, dusty sands, sand) predisposed to liquefaction. On these grounds, the influence of seismic shock can cause sinking and important distortion to constructions. The clay deposits and dry loess are suitable for building but being saturated with water will make the earthquake rise with one degree. In order to assure the resistance and stability of foundations in Chisinau county it is important to follow the norms set by the lithology and morphology of the ground when projecting and executing the foundations.

About 37% of the intra-villain grounds belong to the category of high risks under seismic aspect, and their consolidation and valorification implies substantial financial and material costs. What worries the most is the fact that people make modifications on their own which affect the structure of resistance of the flats, which considerably reduces the stability of the construction.

Chapter V - "The relief - support and resource for urban development and systematization of Chisinău municipality", is the central chapter in this paper. The geomorphological features of the Moldavian Central Plateau are analyzed – unit to which the investigated object belongs; the role of the relief in the development and urban aesthetics, the morphometric characteristics and the genetic types of relief.

The geomorphological context, in which the urban settlement was established and developed, reflects the morphology with the dull-looking hilly relief in the south-eastern part of the Central Moldavian Plateau. Thus, the morphological contact between the plateau area and the plain area is reflected in the existence of the relief specific to these units. The southern and the western side of Chisinău municipality have specific features of the plateau hilly relief with slightly inclined interfluves, strongly nippled or flat, whose width varies between 500 m and 1-2 km. In some places, the land narrows up to 150 m. The northern and eastern sides, afferent to the plain relief, is characterized by sloping hills, with an intense morphodynamic, determined by the landslides and erosion processes. The central part overlaps on alluvial relief (the flood plains and the terraces of Durlesti and Bâc rivers.).

In the context of urban aesthetics, the city has intensely exploited the advantages offered within the geomorphological frame. Thus, in general, Chisinău is considered to be a green city, because most of the forest parks are located on the slopes of the dells and of the potholes, which show an active morphodynamic. The recreation areas arranged as public parks for the urban population occupy spaces within the old stabilized landslide (the park at Buiucani), within the dells (Râscani Park, the Zoo), the potholes (Morilor Valley) etc. The geomorphological support of those four districts Botanica, Buiucani, Râscani and Ciocani represent the levelling and structural areas, with a hilly aspect fragmented by dells, whose slopes are wooded. The old site (Centru district) maintains its original space which includes Bâc flood plain.

The presentation and the interpretation of the morphometric data is important in urban development, thus allowing practitioners to carry out the arrangement and the sustainable planning of the analyzed territory, foreseeing/avoiding certain hazards and geomorphological risks. The storeyed arrangement of Chisinău municipality relief from north-west to south-east is revealed on the hypsometric map (Fig. 36, pg.95, thesis), where 14 classes of hypsometric values ranging from extreme altitudes of this area (20 m and 280 m) are shown. Thus, Chisinău municipality expands between the Central Moldavian Plateau, South Codrilor subdivision, the maximum altimetric quota from this unit being over 300 m and 20 m in Bâc flood plain. The limit between the plateau and the valley sector generally corresponds to the altitude of 220-200 m and passes through the north- west of the municipality. The level difference of 260 m for this area, supported by the petrography, mostly friable, explains the high potential of the erosion and the dynamics of the landslide processes.

The planners, designers, etc. will use hypsometric data to form an overall picture about the relief of the territory. Thus, for the hypsometric map, in the support of the relief assessment as a resource concerning the systematization and the sustainable planning of the urban territory, we considered classes of values with small intervals of 20 m.

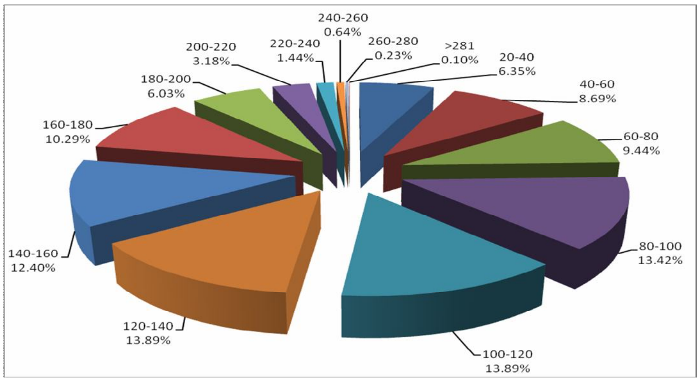


*Fig. 3 The percentage share of the hypsometric steps of Chisinău municipality relie*f.

The hypsometric map points out a total of seven intervals disposed from 160 m (the altitude of the lower levelling surface) until over 280 m for the north –western plateau.

Out of the analyze of the circular diagram of hypsometric steps and the percentage of the representation within the perimeter investigated (Fig. 3) results that the largest share of the municipality surface is owned by hypsometric steps contained between 60 and 180 meters (about

73.33%), while the lower altitudes of 60 m have 15.04% and the ones higher than 180 m - 11.62%. In the north-west extremity of the municipality, which is framed in the South Codrilor high wing, an area of 518 ha has altitudes above 240 m, which represents only 0.97% of the whole territory under consideration.

In conclusion, the largest share of Chisinău municipality surface is owned by the hypsometric steps which are between 100-140 m (27.78% of analyzed area) corresponding to the lower levelling surface 150 m (N3) and to the biggest part of the hilly relief, followed by steps of 140-180 m (22.69%), corresponding to the middle and upper surfaces of levelling 175-250 m (N2, N1) (the western and eastern side of the municipality). In the flood plain sector the highest share is occupied by the step of 20-40 m (about 6.35%) of the municipality surface.

Out of the calculus of the relief fragmentation density and out of the spatial distribution analysis of its values results the morphogenetic features concerning the evolution of the hydrographic network and the intensity of the linear erosion processes in interdependence with the lithological and biopedoclimatic conditions existing at the local level.

The fragmentation density of the relief (fig. 39, pg.98, thesis) for Chisinău municipality has values between 0.1 km/sq km (smoothing surfaces) and 2 km/sq km (in the flood plain sector of Bâc and its affluents). The highest values of relief fragmentation density 1.8 – 2 km/ sq km appear island-like in the analyzed perimeter (their surface is of 3 sq km, respectively 0.57% of the municipality surface). The respective interval is to be found in the south side of Bâc flood plain in the north – west of the municipality (the slopes of Bulbocica dell) and in the flood plain sector of Isnovăt river. Average values of 1.8 -1.0 km / sq km are recorded on the slopes of the affluent valleys and dells and also in the areas with a dense torrential network.

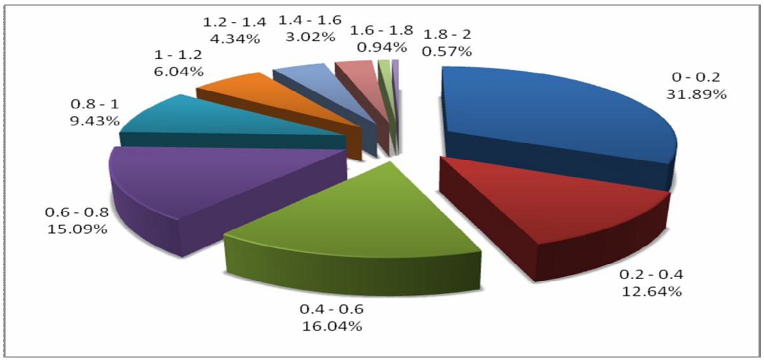


Fig.4 The percentage share of the relief fragmentation density in the municipality of Chisinău.

The low values of relief fragmentation density (below 1km/sq km) are for the 451 sq km, respectively 85.09% of the municipality surface and can be met on all the levelling surfaces (N1, N2, N3) and on the slopes of the dells (fig.4). The lowest values (0.2 km / sq km) in Chisinău municipality occupy the largest area on the right side of Bâc valley, 169 sq km (corresponding to 31.89%).

In the north-eastern and north-western side the fragmentatin density increases from 0.8 to 1.6 km/sq km, a fact explained by a greater confluence report which in turn is justified by high relief energy (at the contact of morphostructural unities) and by the presence of friable rocks.

In conclusion, in Chisinău municipality, low values for the relief fragmentation density are registered (0.1 - 2.0 km /sq km), and their diversity is justified by the morphogenetic features of each subunit (levelling surfaces, the valleys of the dells with slopes affected by gullying, numerous affluents which go down the short and relatively steep slopes of the hills, the petrographic support mostly friable. The analysis of the relief fragmentation density offers us an important geomorphological clue concerning the dynamics and the distribution of the modelling processes from different time stages, dates which will be taken into account in the systematization process and durable development of the researched city.

The depth of the relief fragmentation renders the profundity reached by the erosion vertically, supported by the lithological-structural conditions, being conditioned by the general or local erosion. This geomorphological element has a significant role in the process of systematization and urban planning, because certain types of engineering works will be made according to the degree of relief deepening. For example, the assessment of the land for the road construction and of the characteristic elements: cuts, embankments and their slopes (suitable for run-off, gullying and landslides) will be made on the basis of the relief energy values from the area proposed for arrangement.

The relief energy map (Fig. 42, pg. 101, thesis) highlights the deepening degree of Bâc valley out of which we can infer also its way of evolution (erosion intensity, adaptation to the structure of the valley, the behavior of the rocks at the fluvial erosion etc.). In Chisinău municipality the relief fragmentation depth registers values between 20 m (in Bâc valley) and 140 m (in the north-west and north-east side of the municipality). In the sector of Bâc valley the lowest values (0-20 m) are recorded insularly, having in the same time the lowest percentage of area 2.80%, respectively 14.87 sq km of the entire city area (Fig. 5).

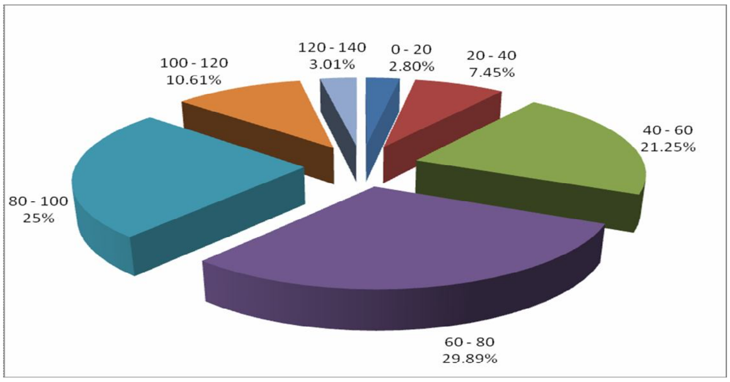


Fig. 5 The percentage share of the relief fragmentation depth in Chisinău municipality

The largest share (29.89%) in the value classes of the fragmentation depth, ranging between 60-80 m, characterizes the levelling surfaces and the slopes with high declivity. Also other intervals (40-60 m and 80-100 m) are added to these unities, which combined with the previous ones occupy more than 76% of the municipality surface, respectively more than 404 sq km, which justifies the high share of the fragmentation depth and yet with small values. It is also noted that the values between 120-140 m have a small share of 3.01% and meet the high wing of Codrilor de Sud.

In the context of urban development applied to Chisinău municipality we further analyzed the dependence degree between the depth and the fragmentation density using the method of linear regression which represents a mathematical approximation.

For this purpose we represented the energy and density values and also their share in the territory. Thus, we determined the equations of the linear regression straight lines (y), the average quadratic deviations (R^2) and the coefficients of determination ($CD = R^2 \times 100$). The value of $R^2 \times 100$ indicates the percentage how many values (y) can be explained on the basis of the variation (x), meaning what percentage of the density values is explained by the relief depth values.

For the fragmentation density, we made a regression with a logarithmic function (A), because it seemed that it would best approximate the data of the density. In both cases we used the regression curve for the approximation. For the territory of Chisinău municipality a correlation between these morphometric indicators was observed. Also, for the fragmentation density was obtained $R^2 = 0, 901$ and a CD = 90%. For the energy relief was obtained $R^2 = 0, 8675$ and a CD = 86%. From these data it can be inferred that Chisinău territorial level provides a correlation between the depth of the fragmentation and the fragmentation density due to the homogeneity of the relief and of the lithological conditions predominantly friable etc.

This morphometric parameter plays an important role in the urban geomorphological study because according to the values of the recorded declivity, combined with other quantitative indices determines the type and the size of the constructions suitable for certain types of relief, forecasting the morphodynamic of the territory. Therefore, the stability of the relief forms proposed for the arrangement is in tight connection with their slope and lithology. In this context, we mention that in the analyzed territory even the areas with small slopes (2-5 °) attest vulnerability, because they consist in preponderantly friable deposits (loamy, clay, loess).

Thus, the variation of the geodeclivity in Chisinău municipality is closely connected to the geological support and the actual modeling of the relief. In this respect the values of the morphological surface gradient were divided into six classes, taking into account the morphodynamic nature of the researched perimeter and of the applied character in what concerns the urban development of the locality.

By analyzing the slope map (Fig. 45, pg. 104, thesis) there is a difference between the declivity values in the valley sector of the researched area and those recorded in the adjacent areas, the hills and the knobs from the plateau unity. Given the significant share of surface smoothing, of the slightly inclined slopes and of the wide Bâc valley, the percentage of the surfaces with a slope of up to 5 ° exceeds 58% of the entire territory of the municipality. The morphological units with the declivity between 0-2° are suitable for constructions, having restrictions in the case of ample works with significant charge, because the risk of subsidence and infiltration occurs. Apparently the surfaces slightly inclined (2-5 °) are favourable for urban development, but the preponderently friable lithological conditions reminds us that the slopes higher than 4-5 ° obstruct certain constructions, thus existing the risk of shallow landslides (Orlov, 1982).

A large proportion (32.23%, respectively over 170 sq km) in the value classes of the relief declivity stands for surfaces comprised between 5-10 °, characterizing the slopes, in general, or certain units of the slope. Areas with large slopes which exceed 10 º, such as the steep slopes affected by landslides and torrentiality, make up 8.32% of the city, respectively totaling 44.17 sq km. Overall, the areas with the highest values of declivity (over 15 °), appear insularly and cover about 3 sq km (respectively 0.56%) of the total area of the municipality (Fig. 6).

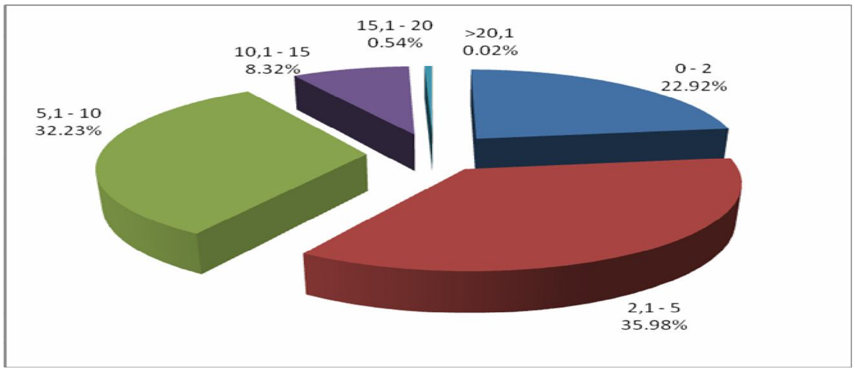


Fig. 6 The percentage share of the relief declivity in Chişinău.

In relation to the above mentioned, we believe that the fragmentation density, the fragmentation depth and the declivity of the analyzed territory represent the basic quantitative characteristics which indicate the evolutionary appearance and the evolution trends in current modeling processes (fluvial-denudational, landslides).

The exhibition of the slopes in the territory examined is determined by the orientation of the north-eastern slope of Central Moldavian Plateau (Codrilor de Sud subdivision) on which Bâlc river is grafted. This is mirrored in the overall share of the urban territory exhibition, as the slopes with north-eastern orientation (shaded) holds 21.12% (Fig. 8) of the total municipality, respectively around 112.14 sq km.

Also, according to the general direction, imposed by the direction of the sylvan crests fragmented by Bâc river, we remark the exhibition of the hydrographic secondary basins, the direction of the affluents and the degree of hydrographical network branching. Bâc river with its main tributary Isnovăt, presents a general north-south direction and a mostly linear basin (unbranched), so that the shaded slopes prevail (predominantly north-eastern orientation) and the sunny ones (south-west) (Fig. 47, pg. 106, thesis). Durlesti tributary is an exception, which starting from its origins follows the north-south direction and in the area of Valea Morilor lake changes, taking a general south-north direction. This implies a predominantly northern orientation, north-eastern (shaded) and respectively southern, south-western (sunny) for the nearby slopes.

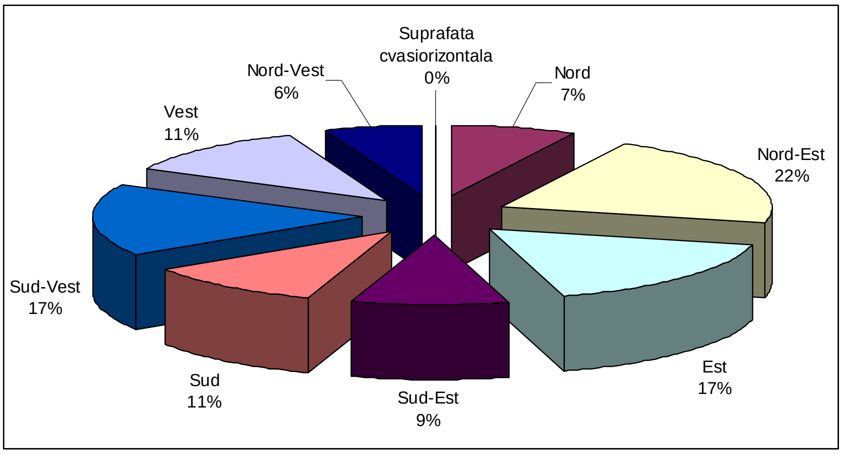


Fig. 7 The percentage share of the exhibition of morphological areas in Chisinău

The exhibition of the slopes in the urban perimeter distinguishes itself by the fact that on the right side of Bâc valley the slopes with north – eastern and and eastern orientation prevail.

Also, the slopes of the dells to the right of the valley have a predominantly western and north-western exhibition. Another situation is observed on the left side of the valley, because the slopes with south-western, western, south-eastern and eastern exhibition prevail. The insolation duration, conditioned by the exhibition of the inclined areas is high, taking into account the fact that the sunny and the half-sunny slopes occupy almost half (48.39%) of the total area of the municipality (Fig. 7).

In the attention of the practitioners will be particularly the slopes with western orientation (half-sunny) and northern (shaded) (18.94% respectively over 100 sq km) which receive with 15-20% more precipitations than the opposite surfaces. Therefore, the over-damped flanks maintained by loose friable deposits are pieces of land suitable for the development of the linear forms of erosion and for the landslides. Regarding the process of urban systematization of these areas,this one will focus on building stability, improving the setting land or if necessary even to be avoided.

Chisinău municipality, regarded from the morphographical point of view appears as an association of positive forms (levelling surfaces, structural surfaces, erosion witnesses) and negative (valleys, dells, potholes) with relatively smooth interfluves and with a predominantly low relief energy. The genetic types of relief which constitute the current geomorphological framework where Chisinău municipality develops can be grouped into four categories:

1. Polycyclic relief:
   - levelling surfaces
2. Petrographic relief:
   - structural surfaces
3. Fluvial relief
   - river beds and flood plains; terraces and slopes
4. The denudational relief resulted:
   - through linear and areal erosion

The polycyclic relief from Chisinău boundaries has the aspect of some large fields with slight tilt towards south-east. In cross section the areas are asymmetrical, with the edges scalloped by concave or convex lines and strongly fragmented by the system of dells and torrents. The micro relief is completed by the negative forms of pipping, settlement and by the antropic ones. According to the geomorphological map (Annex 1), on the researched territory three levelling surfaces are outlined: upper, middle and lower (Table I).

The territory of Chisinău municipality has a relief developed on a concordant horizontal and subhorizontal structure with slight tilt towards south-east. The landforms imposed by this structure are directly related to the sedimentary lithology, and also to the stages of morphologic evolution of the studied land. Therefore, within the urban area structural surfaces are identified, developed on hard rocks (Sarmatian limestone), covered with friable deposits of variable thickness up to 15-20

m. The lithological variety (clay, sandy-clay, sand, loess) met in the limits of Chisinău municipality is closely related to the landforms of the territory.

In line with the above mentioned, in the area studied were distinguished the following types of petrographic relief: *the relief developed on clay*, *relief developed on loess, the relief developed on sand*.

The relief developed on clay and loamy facies is characteristic to low slope areas, to interfluves with round and flat aspect. These deposits predominate in the territory and intercalates with sands. The water drainage from rainfall is rapid due to the impervious clay and where the vegetal cover lacks, small sillons and cloughs appear. Due to high plasticity, while wet these formations give birth to frequent landslides. In general, within the urban hearth the clay deposits have generated a relief in which the landslides play an important role (Petricani, Buiucani, Malina Mică, Valea Morilor, etc.). In the investigated area the sand determined the relief with slopes reduced by the dripping processes and by the torrential erosion. The specialists in engineering emphasize the fact that the fine sand with round and identical-sized particles is settled and has low bearing capacity. While the compacted land is not settled, thus the bearing capacity is higher (Manoliu, 1984).

Table I *Levelling surfaces within Chişinău* municipality

Levelling surface	Altitudes	Aspect	Territory location
Superiour (N1)	(250-300 m)	- wavy interfluves, narrow, with widths ranging between 200-750 m and 100-150 m; - erosion witnesses, saddles	- north-western side of the municipality
Average (N2)	(175-200 m)	- broad smooth plains, slightly wavy, more expanded on the width (250-1000) but from place to	- the western, eastern and north-eastern side of the municipality. - the south – west (Botanica) and the west of the intravilan (Codru)

		place it narrows until 50 -60 m; - round erosion witnesses (which exceed 180 m), saddles.	
Inferiour (N3)	(> 150 m)	- as fields predominantly flat, with widths ranging around 2 000 m -strongly nippled -we notice a distinct trend of tilting towards Bâc valley	- dominates in territory, but they are more extended in the eastern, northern and southern sides of the municipality. - prevails within the limits of the hearth

The relief developed on loess in the urban perimeter of Chisinău presents various forms, of small dimansions and less resistant over time. The dislocation of the loess as slices (foto. 1 (a)) is a characteristic for the morphology of the land. Also, the collapse in steps is outlined in the slopes and in the levelling areas, especially where there are steep slopes. As a result of the pipping, the pipping funnels arise, which continue in the depth with a sinkhole, which runs through the whole thickness of the deposit (foto. 1 (b)). Specific to the loess of 15-20 m thickness are the settlements which are registered (especially in Buiucani district), as a result of the intense urbanization process.

a.  b. 

Photo 1 Modeled landforms modeled on the loess in the north side of Chisinău municipality

Created by the erosion process of the river, Bâc valley with its elements (the river bed, the terraces and slopes) is the main form of relief that attracted and caused the subsequent development of Chisinău municipality. The minor river bed reflects the nature of the loamy fine structures, which predominate in the major river bed.

A feature of the drifts is that, these ones are in a periodic movement and in the longitudinal section we remark an obvious tendency of sorting the deposits. When the river is drifting abundantly the islets are formed (photo 2).

Photo 2 The antropization of Bâc river in the central part of Chisinău municipality.

Bâc river, practically on the whole length of its course is accompanied by a major river bed which has continuity on both sides. Bâc flood plain is well defined on the largest spread, presenting in certain sections local bottlenecks that go up to his disappearance (Annex 1). In terms of morphology, Bâc flood plain is characterized by its flat-bottom, scalloped with fluvial grinds, cones of dejection which tend to be blurred by the works specific to the intense urbanization process. Out of the negative forms the anthropogenic forms are remarked: pits, excavations, etc.

The demarcation of Bâc river terraces for Chisinău municipality represents the relief forms which perhaps generated the highest number of debates. Studies of fluvial geomorphology of Bâc river do not exist at present. The most credible explanation, in what concerns the number of Bâc terrace levels, is brought by Bilinchis and his collaborators (1978), who defined five stages.

After analyzing the topographic maps at the representation scale 1: 25 000 and 1:50 000, as well as profiles made in the field, we specify the following aspects:

• in what concerns the number and the relative altitude, terraces fall into the overall system observed also by other researchers, being a number of 5 stages;

Table II *The terraces within Bâc Valley. Number and altitude.*

No.	***T I***	***T II***	***T III***	***T IV***	***T V***
Relative altitude(m)	*18*	*30-35*	*55-60*	*80-90*	*90-110*

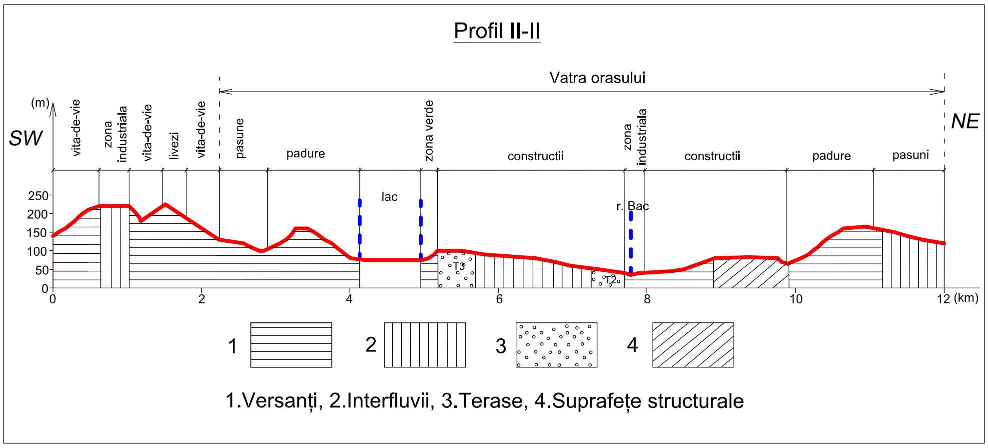
• in terms of spatial arrangement these ones shall be identified in isolation but also in groups, especially on the right side of B*â*c valley

• the alluvial terraces with well-conserved deposits prevail

Analyzing the geomorphological map (Annex 1) in the longitudinal profile of the valley shows a predominant distribution on the right side of the terraces. The 18-meter-long terrace is identified only in the downstream of the urban hearth on the right side of B*â*c valley. The 30-35 m terrace and also the terrace of 55-60 m is best represented by both the frequency and length, width. The foreheads of the terraces are barely sketched on one hand due to the denudation processes (by inserting the bodies of the torrents, landslides) and on the other hand due to various urban arrangement works. The 80-90-metre-long terrace appears fragmentary only on the right side of the valley in the central part of the city, being fragmented in dells. Also, the terrace of 90-110 m is the level with limited development in the longitudinal profile on the analyzed territory.

Although the slopes limit the full exploitation, at present they are highly exploited and involved in the process of development and urban expansion of Chisinău municipality (fig.8).

Taking into account the geomorphometry, the morphogenetic processes and the constitutive deposits, these forms can also be suitable for the urban arrangement activities of the municipality relief.



1.slopes, 2. interfluves, 3. terraces, 4. structural surfaces.

Fig. 8 The transversal geomorphological profile executed in the central part of Chisinău.

Some general features concerning the morphology of the slopes are inferred on the basis of the field research and accomplished sections, having as support the topographical maps with the scale 1:50 000, the geomorphological map (annex 1):

- The simple slopes with radial profile prevail (concave, convex, linear), but which, being maintained by the substrate, slope and design overload, are forms with natural fragile balance. While these inclined areas have become areas of intense concentration of urban constructions, even in areas exposed to geomorphological risk (Petricani Telecentru, Morilor valley, Telentru etc.) the analysis of the profile lines reveals the following major types of slope profiles:

The convex profile – it is characteristic to the slopes which are in a state of relative equilibrium, as a result of redistribution of adobe materials. Despite the tendency of profile levelling, there can be noticed a segment of maximum concavity, in the upper sector of the slope and a linearity tendency towards the base, where they recorded the highest declivity of the profile line (e.g., 10 °, at the basis, in regard to 4° or even less, towards the superiour sector). It is characteristic to the slopes of the dells and also to the primary slopes of B*â*c (Fig. 9 a, b).

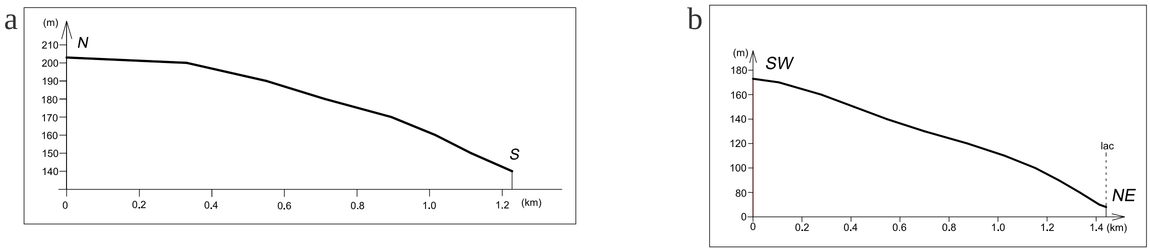


Fig. 9 Slope profiles: a) convex profile made on the right slope of Bâc, near Ghidighici lake; b) right and slightly convex slope profile, conducted in the south-east of Botanica district.

The concave profile - this type of profile reflects the lithological constitution of the slope. The dominance of the clay, sandy clay generates concave profiles, which are executed by the withdrawal process. We notice the upper sector with high declivity (9-10 °) subjected to further erosion and the lower sector with low declivity (2-3 °) where the accumulation of the deluvio-colluvial material takes place. (Fig. 10).

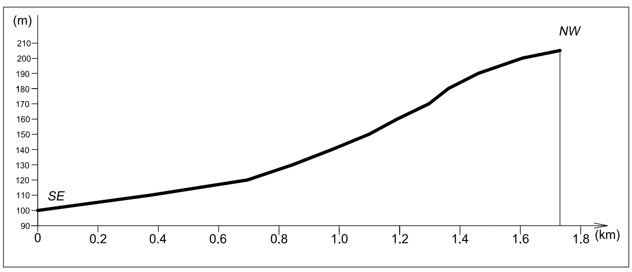


Fig. 10 Concave profile made on the slope of the dell from Codru locality (embedded in Chisinău municipality).

The linear profile – these are characteristic to the indirect slopes of B*â*c river, resulting from the deepening of the dells through torrential erosion. The linear slopes denote disequilibrium at the level of the valley-slope system within the dells through the uniform removal and the uniform redistribution. The slopes of such profiles are mostly planted with grass and trees (figure 11).

a b

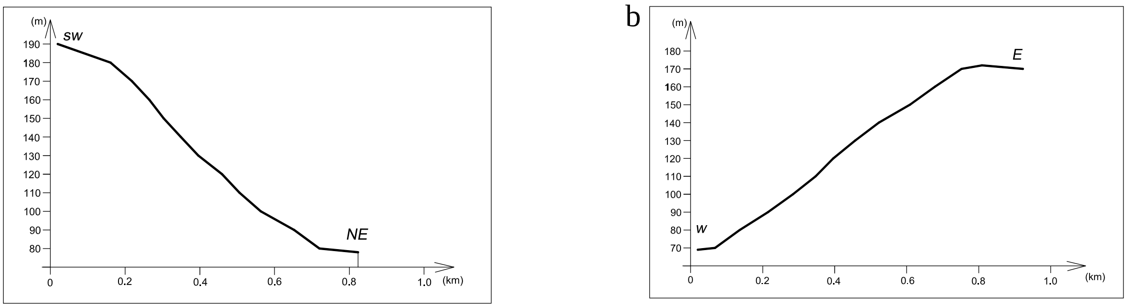


Fig. 11 Linear profiles: a) carried on the upstream slope of side of Valea Morii lake, b) on the left slope of Râscani dell.

- The focus will be on the denudation/ wasted slopes which can be met on both sides of the valley from the urban and suburban space. This fact requires the monitoring of the modeling processes and of their intensity especially in spring and autumn;
- Another aspect that must be mentioned here is that urban arrangement works (digging, plowing, agricultural terracing, accumulation of waste, etc.) determined the natural transformation of the slopes. As a result, slope portions with anthropic profile in steps have been created, and where the natural form was preserved are attested landslides, incipient cloughs, surface erosion and adobe accumulations (Telecentru, Petricani, Botanica, Valea Morilor, etc.).

Thus, the study of the slopes in Chisinău municipality in an applicative context, will unroll with the static components out of which the form of the slopes is very important. Its complex analysis will compulsory be made in direct proportion to: ***petrography*** (because in the researched area is predominantly of sedimentary nature / friable sensitive to overload and water) and the ***geological structure*** (which will take into account the orientation and the inclination of the strata, the alternation of the deposits with different resistance to erosion).

Further, given the morphology of the slopes, we will try their standardization according to several criteria (table III). The classification will reflect how the slopes were and are used in the process of urban development of Chisinău municipality, also the data are useful to the practitioners in highlighting the risky areas where the human intervention will be made with caution.

Table III *The classification of the slopes in Chisinău municipality*

No**.**	Criterion	The classification feature	The type of the slopes
1.	Morphometrical	*According to dimensions (length, width, height)*	- slopes with medium size (150-175 m) [the slopes of the dells, hills]; - slopes with reduced dimensions (>100 m) [the banks of the rivers, cloughs].
		According to the size of the slope	-inclined slopes (15-25º); -slopes with medium bent (8-15º); - low inclined slopes (4-8º); -very low inclined slopes (2-4º).
2.	Morphographic	*According to the form of the profile line*	- linear slopes; - radial slopes (concave, convex); - mixed slopes
3.	Evolutional	*According to the dynamic equilibrium*	- slopes in relatively dynamic equilibrium
4.	Structural	*Imposed by the geological structure*	- slopes with conform orientation; - slopes with converse gradiation; - insequent slopes
5.	Ordinary	*According to the degradation degree*	- slopes with medium degradation; - wasted slopes.

The general evolution of the slopes in Chisinău, has become more and more complex now due to intense urban arrangement activities. It is characterized by a summation of secondary modeling that lead towards the withdrawal of the inclined slopes and the fragmentation of the quasi-horizontal surfaces. Surely is the fact that the process of actual modeling is influenced in particular by petrography (of non friable nature: clay, sandy clay, loess, etc.), by the slope, by the depth of the underground water, by the degree of vegetation cover, etc. Also, the urban anthropic factor will cause the cracking of the unity of these systems, gradually involving the entire slope in a slow process of evolution, which eventually will turn into a low-sloped equilibrium surface.

On the sixth chapter "The Topical Shaping of the Relief", we present the gravitational processes and the area shaping forms; fluvio-denudational processes and the anthropic influence over the actual shaping of the relief.

Once, however, with the urban enhancement of the localities, specially beginning with the second half of the 20th century, we can see an accelerated rhythm of capitalization of the researched territory, and respectively of the relief. As a consequence, this expansion phenomenon redounded to the apparition of another one, which is specific to the urban locations founded on loesses. It is about ***"water dome"*** phenomenon, generated by the derivate seepages from the flaw conducts exfiltrations and chaotic drain of the meteoric and domestic waters, which's perpetuation pervaded the massive deposit of loess.

For example, the Botanica and Buiucani neighborhoods are embedded on a massive deposit of loess (10-15 m) at which's basis we can find a chersonian clay horizon, which upkeeps and favors the ascension process of the underground water. Particularly to Chisinau, connected to the "water dome" phenomenon it is relevant the fact that, the superumectation doesn't take place through infiltration (from the surface in depth), but vice versa, in the ascending direction (from the depth to the surface).

About this phenomenon Orlov and Co. (1988) noted that, on the Centru neighborhood the water-bearing level during 110 years (from 1840 to 1950) raised with approximate 2 meters. While during three years (1960-1963) on the same surface water-bearing level raised approximate one meter. So, during this stage downtown the depth of the phreatic water is about 2.5-3.0 m, and not 10-15 m like in the 60' of the 20th century. Hence, this phenomenon represents a favorable condition for the break-out and the manifestation of the slip in Chisinau city.

The settlement has an important role on the actual shaping of the Chisinau city's relief, constituting a risk factor for some areas (Budesti, Botanica, Buiucani). The manifestation causes of these processes on the urban perimeter are multiple. We have to mention the fact that the deformations and the possible risks at the constructions level may occur by neglecting the whole complex of the protection norms of the terrains which are subject to settlement. For example we have the deformations which appeared as a result of the settlement on the nine floors block from the Moscow prospect (Rascani neighborhood).

On the researched terrain the creep is hard to observe. The movement and the rearrangement of the particle depend in every single moment and at every single particle by the local and casual circumstances.

Similar to this situation **the creep** took place in Chisinau city during 1995 and 1996. The creeping phenomenon and the inflexion of the trees ("drunken forest") were registered on the right slope of the Bac River, Buiucani neighborhood (near Butoias restaurant). The apparition of the process was facilitated by the temperature variation and the moisture degree, by the water infiltration and the herbal and wooden vegetation abundance (Volontir, 1995). For the moment the process is stabilized in this area.

The slips have a priority role on the slope shaping system of the Chisinau city (fig. 58, pag. 135, from the thesis). These mass displacements constituted a subject of knowledge for a lot of researchers from diferent domains (Porucic, 1929; Drumea, 1963; Jeru, 1963; Orlov, Ustinova, 1963; Fedorcenco, Şcicica, 1974; Tcaci and co., 1981; Râmbu, 1982; Levadniuc, 1983; Capcelea and Co. 2001 etc.).

Because the capital-city is constrained by the exhausting of the funds designated to the territorial extension there are made different engineering works at the dales level (Schinoasa, Gâştelor, Valea Morilor, Malina Mică, Malina Mare etc.) fact which conducted to the prosperity of the lands affected by falls and the acceleration of the degradation rhythm, both in the urban and periphery area. This fact is confirmed by Orlov (1988), 70% of the slips from Chisinau city are caused by anthropic activities and just 30% are the result of the natural factors.

Concerning the age of the slips from Chisinau city some researchers (engineers, technicians and geographers), use too *"the ancient slips"* category, regarding the slips from the prehistoric period, framed in different geological periods of time, which broke-out a long time ago the old ones (pleistocene). These aspects helped us to elucidate the general evolution of the old and "ancient" slips, cert is the fact that overall they are massive with variable thicknesses (8-15 m; 20-25 m), and from the point of view of the surface they are over tenth hectares. In our days the component parts of the old slips are heavily stopped (the forehead, body configuration, etc.), and the degree of stability is obvious. Therefore, the old stabilized slips have a normal predisposition to present new activations or reactivations. On the same idea, Surdeanu (1993) testifies the fact that "the actual slips represent innings of reactivation of the old ones", also Sarodoev and Co. (1993) affirms that 90% from the new slips are developed on the old ones.

Concerning the morphological traits of the slips, on the scenery are imposed the **flowing-ellipsoidal slips** (like a tongue) and **mixed slips** (blocovo-plasticeskie). Less evident but present in territory are suspended slips. From the structural point of view this type develops like consequent slips, taking into account the terrains with quasi-horizontal layers. Usually, the main detached area has a medium height of 2-5m. Thanks to the presence of a tinny rocks layer (our case limestone), the slip's body has a linear form which is suspended over these structures (fig. 12).

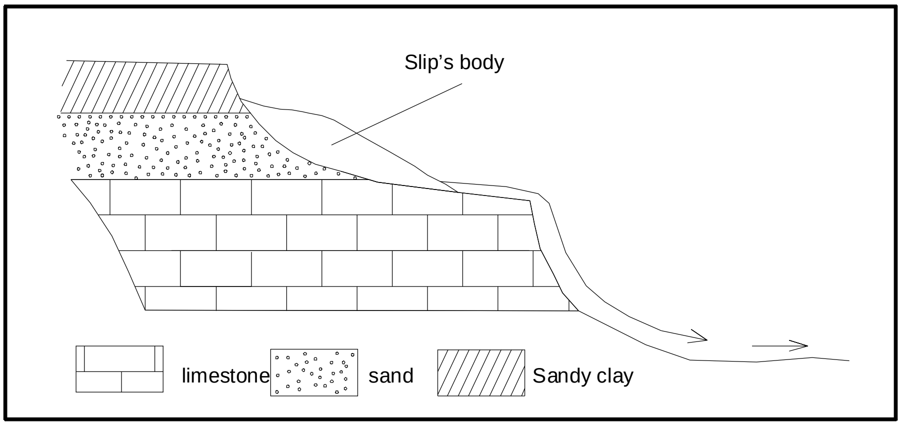


Fig. 12 Suspended slip

The determined risk by the slips is one of the top priority spot on the researched terrain, having a direct impact over the urban infrastructure (buildings, homes, ways, high tension lines, etc.). In this respect, we have an example on the slips which accompany the slopes from the Petricani area, being sustained by petrography, intense moisture conditions, slant, overloading of the slopes with buildings, etc.

The whole slope from the aero photogram (fig. 13) is affected by old slips, reactivated, for the moment fixed and terraced. On the image we can observe how the right slope of the Gastelor dale (dells) is affected by actual slips in different phases of evolution, mostly stabilized through anthropic arrangements. On the right slope of the leveling surface (Agrarian University is place on that surface) we can observe an active slip which evolve on waves series, these being stabilized (through deep drainage, where is collected the underground water from the whole surface of the slope, through reinforced concrete ditches thru which the water is drained on the surface). Also, downward the forehead of the slip is stabilized through a support wall. For the buildings situated a little bit upper of the detached area of the respective slip, for the downward garage and the communication line between Mircesti and Petricani, the slips were and are for the future an imminent risk.

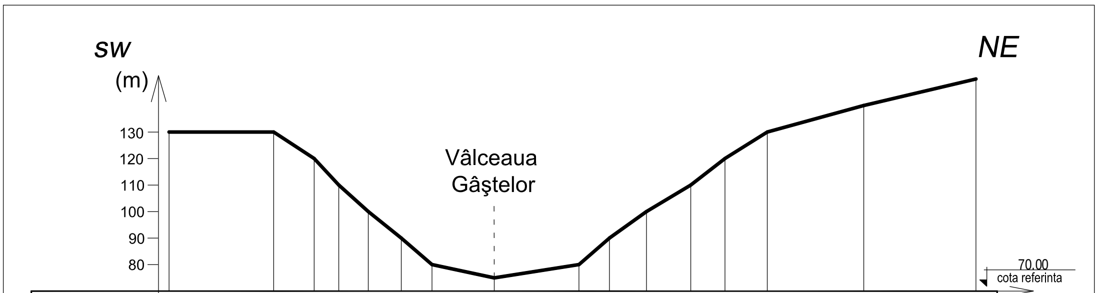
Fig. 13 Slips from Petricani area, the right slope of the Gastelor dale

According to the presented data from this chapter we can easily conclude the fact that, on the slopes profile from Chisinau city flaunt, specially, sectors with slips from different generations. Also, notable is the fact that at the slopes level we distinguish ***particular areas of processes and relief forms***, locally named *bump*. Through the notion/shape of ***bump***, T. Porucic (1929) understood: „ a hollow which through hundreds of years transforms into a circus form valley, namely a valley with a structure in amphitheatre of variable dimensions: the diameter from 100 m to 3-5 km, the depth from 5-10 m to 50-100 m”. This identification permitted later to the researchers: Proca (1970), Podrajanschii (1970), Râmbu (1982), Levadniuc (1983), Capcelea (1992) the confirmation of the adequate shape, the argumentation and the completion of the notion.

According Proca's (1970) data, „*the bump represent massive erosion and slips circuses with an amphitheatre aspect, inside of which are delimited the very inclined cornice and the big bodies of the old slips*".

In this context, the identified bump from Chisinau city, represent massive relief shapes (with diameter between 250 and 1000m) composed from several generation of erosion circuses with old and actual slips – actives, fragmented by the concentrated erosion forms (gullies, cloughs and torrents). The depth varies from 40 m to 100 m, bump's cornice have a big declivity between 10 and 15 degrees. For example we studied the Valea Morilor bump (fig. 63, pag.150, from the thesis).

From the fluvio-denudational processes category take part: pluviodenudation (the in surface washing) and linear erosion, which are totally retrieve on the Chisinau city area, even if the clough and, especially, the torrentiality are much more limited. The clough process turns off with the achievement of an equilibrium which consists of grass cultures on the shores and on the bottom of the clough. Therefore, the stabilization phenomenon (equilibrium) is an integrative and complex one, on morphological score results the *dale*. The frequency of these forms constitutes the fundamental trait for the researched urban space (fig. 14). On the most part of the analyzed territory, the dales are remarked on the relief through autonomic valleys of small dimensions with a linear profile, with little leaning slopes (5-7°) on which are observed and abrupts (15-20º). The lenght of the valleys varies, generally, being over 1000m, the width over 250 m, and the depth reaches 60 m. Also, the cocave bottom of the dales is mainly grassy, fragmented by long valleys sculptured by permanent brooks (only during drought is remarqed the narrow of the water beam or even the depletion on several parts).



Nr. punct	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dist. cumulata [m]	0.00	197.50	273.90	320.35	376.03	438.27	496.34	613.86	773.71	831.31	901.22	984.83	1049.34	1129.22	1311.38	1523.15
Cote [m]	130.03	130.03	120.02	110.02	100.02	90.02	80.02	75.00	80.02	90.02	100.02	110.02	120.02	130.03	140.03	150.03
Dist. partiala [m]	197.50	76.40			62.24		117.52	159.85		69.92	83.61	64.51	79.88	182.16	211.77	
Panta [%]	0.00	13.09			16.07		4.27	3.14		14.31	11.96	15.50	12.52	5.49	4.72	

Fig. 14 Transversal profile of the Gastelor dale situated on the NE part of Chisinau city

Concerning the geomorphologic activities of the human beings which significantly influenced the aspect of the environment from Chisinau city, these are connected to the transformation of the territorial morphology through the engineering works (embankments, industrial and civilian constructions, roads, etc.).

Concurrent with the intense urbanization process of the Chisinau city (the 80's, the beginning of a new development inning) evolved the prospecting and the exploitation of the building materials both in underground and on surface. From the economical point of view the discovery and the utilization of the building materials (limestone, rubble stone, clay, sand, gravel) near the building yard was a profitable effort. But, the accelerated rhythm of the building materials consumption guided to the multiplication of the affected areas by anthropic actions, resulting a *geomorphologic degraded landscape*.

Chapter VII , "Perspective of Territorial development of the Chisinau township, at this moment the Chisinau" township goes through an economical crisis regarding the funds destined to territorial development. Consequently, one of the most actual aims of the urban planning is how to use efficiently the areas within and outside the city limits. It is a fact that, that at the present, the development is mostly focused on green areas such as parks, and on dells ´slopes in the areas that have been already built on. This has a negative effect on the city´s environment as well as on the areas prone to mass wasting. This solution is not the most favourable one, as the accent moves toward the *city´s vulnerability*.

The geomorphologic imbalance in the study areas is due mostly to mass wasting processes, linear erosions and to an overall decrease in the quality of the terrenes. Their impact, added to the impact of floods, for example, on the city environment is visible in some areas, as one can see on the Terrenes vulnerability Map (Fig. 67, p. 167 thesis). In this map, I classified the city´s surface in areas that are a reflection of the processes that affect them. The effect of flooding, mass wasting, linear and areolar erosion have been considered in the development of the map, and consequently, the following areas have been identified:

- vulnerable areas because of high level of humidity and flooding: Bacului flooding plain, its tributaries and the small adjacent valleys;

- vulnerable areas because of mass wasting processes: areas of old landslides that have been reactivated, of actual landslides, of landslides that have been recently stabilised;
- areas of low vulnerability: areas that have been affected by presently stabilised old landslides and slightly inclined slopes prone to mass wasting processes (e.g. slopes of the dells);
- areas of no vulnerability: areas on top of the fluvial divides.

The Chisinau vulnerability map aims to be used as a tool in the sustainable urban planning processes.

The second main idea of this chapter is focused on the perspectives of urban development of the Chisinau City in relationship with the geomorphology of the area. The state of emergency generated by the absence of necessary terrenes for the urban development, as well as the identification of areas at risk are actual issues that need to be considered when talking about the sustainable development of the Chisinau township. Consequently we created the *urban geopotential map* (Fig. 68, p. 169 thesis). Factors that have been considered in the process were: the susceptibility degree and the evolution stage, as result of the actual modeling processes. Four areas have been identified, regarding the <u>pretability</u>: *high, medium, low and very low.*

At the present there is an obvious tendency to build on the areas of relief with <u>medium pretability</u> (towards the south limits of the city) – slope with a maximum altitude of 150m and small declivity 4-5º, as well as on the narrow fluvial divides areas (up to 250 m). The main issue for these areas is that some controlling factors can potentially develop locally an imbalance. More specifically, in the case of Chisinau, some areas that have been identified as old stabilised landslides are used in the urban planning. The imbalance in these cases can reactivate the old landslides with negative impact on the population.

The areas with <u>low pretability</u> are those areas along the steep inclined slopes and highly fragmented by the dells (dale) with a passive morphodynamics. The majority of the degraded slopes with an active morphodynamics belong to the areas with <u>very low pretability</u>. On the already developed territory, the high geomorphic risk areas are as following: Buiucani neighbourhood (east side of the Morilor Valley, Sfanta Vineri dale), in between Rascani and Ciocani neighbourhoods (Tiganilor dale, Ciocani); the south-east side of the Botanica neighbourhood, etc. On the outskirts of the city, the areas with low and very low pretability are localised mostly on the left bank of the Bac River, but also on the right bank of the river towards Codru village. A favourable situation for the urban development of Chisinau would be an eventual development on the agricultural areas from the outskirts of the city as well as on the agricultural areas belonging to the close by localities.

The main ideas of this study, as well as the conclusions are the result of the morphometric and morphographic analysis of the urban territory, focused mainly on the buildings stability; identification of areas at risk in the context of building development as well as delimitation of areas of pretability that enhance the perspectives of sustainable development of the capital city.

GENERAL CONCLUSIONS

This study shows that the Chisinau township territory is located in an area with a geomorphology that is favours urban development. The downside is that the urban development along time did not consider always the relief, which led to a visible transformation of the later, and today there are clear geomorphologic risks that have to be taken into account.

Worth to mention is the fact that the areas modeled by the natural processes have been strongly affected by the human activities within the drainage basin all the way up to the river divide.

The geomorphological researches on the study area have mostly a general character, focused mainly on the morphology and morphodynamics of the Podisul Central Moldovenesc (Porucic, 1929; Drumea, 1964; Orlov, Ustinova 1969; Proca, 1970; Bilinchis, 1978; Levadniuc, 1983 etc.). Also, in the case of urban territories, the studies have a general character (Constantinova T., Sârodoev et al., 1993; Capcelea, 2001), or have a limited approach (Drumea 1963; Fedorcenco, 1974; Tcaci et al., 1981; Orlov, 1982; 1984; 1988), focusing mostly on landslides.

The issues related to the territorial development of Chisinau; the actual trends of sustainable development of the capital city; the absence of a urban geomorphological study lead us towards the purpose of this thesis named: "Geomorphological assessment for a sustainable urban development of Chisinau township". This thesis is a geomorphological study applied to urban development. Urban applied geomorphology plays the role of "determining" the relief: managing and assessing the different degree of pretability of areas. Depending on these factors the proposed development areas are going to be utilised to a maximum.

In this context, the present study has as focus determination and establishment of the urban strategies so that Chisinau City would be provided with a sustainable development plan. Consequently, the research enhanced the *favourable physical-geographical* factors (climate, edaphic factors, river input) and *limiting factors* (such as geology and the relief) in relationship with the urban development process.

Actual, the morphology of the urban area, that is affected by the human activities is characterised by:

- the geomorphological frame: the area in which the city started and continued to develop is demonstrating the morphology with a very monotonic hilly relief from the south-east part of the Podisul Central Moldovenesc. Consequently the contact between the plateau area and the plain area creates relief specific to those types of units;
- Bâc River valley: avec all its elements (drainage, terraces, slopes) is the main relief feature that attracted and determined the future evolution of the locality Chisinau. Bacului valley runs NW-SE, and it is characterised by a visible asymmetry: left bank has higher altitudes and it is higly fragmented; right bank is wider and is characterised by fluvial terraces;
- actual relief of Chisinau area is the result of multiple geomorphological processes (solifluxion, creep, landslides, ´´water bell´´ phenomenon; ravines) that during time have been controlled (strongly or not) by the natural localised condition;
- urban planning led to an accelerated process of using the geomorphological support in constructions; that led to the use of high risk and medium risk territories, such as: overloaded slopes, raising of the aquifer levels, etc. These processes had as effect activation of landslides;
- landslides in the Chisinau area are at the moment in a slow phase, giving a false impression of stability. This aspect is proved by the slow evolution of the landslide processes;
- while landslides are a constant presence in the Chisinau Township, the ravines and the torrents are limited.

In the present the extent of the Chisinau city is limited by the very small number of areas that are available for the development. Consequently, the urban development happens within the city on the areas with medium, low and even very low pretability. There is the possibility that in the future the urban extent is going to be controlled by the acquisition of agricultural land from the outskirts of the city. The Chisinau city has reserves of favourable relief for the urban development that could spread towards the closeby localities. The development can be oriented on favourable directions (those ones that do not need special improvements), but also on the not-so-favourable directions, but only if very expensive improvements can be done.

***The SWOT analysis* on sustainable development of the municipality Chisinau.**

Strong Sides 1. The geographic environment conducive to urban development. 2. The bio-pedo-climatic basics favorable. 3. The predominance of low average annual flow protects the city from flooding. 4. The land resources are conducive to creating green spaces. 5. The geomorphological potential limited, but sufficient for the urbanization.	**Weak Sides** 1. The lack of space for expansion. 2. Over 37% of built-up lands have major seismic risk. 3. The friable condition preponderant favorable lithologic landslides. 4. The aquifer is at shallow depths. 5. Destabilization of slopes affected by landslides old by urbanization works.
Opportunities 1. The territorial expansion in the suburban areas with high suitability. 2. The development of the major geomorphological risk areas for recreational purposes. 3. Greening Bâcului floodplain. 4. Stabilizing the slopes with high vulnerability. 5. Reorganization of drainage networks in areas with high risk. 6. Sustainable development can be achieved only on the basis of thorough study of the substrate and the morphology of the territory.	**Threats** 1. Lack of legal framework on the management and use of relief depending on the degree of susceptibility. 2. Expanding green areas built over. 3. Overloading construction on slopes. 4. Reactivation of the old landslides. 5. Deplorable state of groundwater drainage networks. 6. Seismic zone. 7. Degraded slopes are the result of human activities. 8. Specialists indifferent mentality on lithology, topography and urban planning current morphodynamic.

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Annex I **Chisinau sity. Geomorphological Map.**