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Geomorphic evolution and present-day geomorphic processes of the southern part of the Crimean peninsula (Ukraine)

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ABSTRACT

The Crimean Mts. in the southern part of the Crimean Peninsula are a tectonically active area characterized by the great dynamics of the formation of the relief, including especially wide landslides and intense development of the erosive shapes. The asymmetric morphostructure of the mountains is the northern limb of the anticline, formerly a vast mountain ridge. The basis for the research was a geomorphological survey and the creation of the database for the geomorphological information system. However, the goal of the work was not only compilation, but the complete recognition of the present geomorphological processes in relation to the tectonic aspects of the development of the relief. Concurrently, thanks to agreement between the University of Ostrava and the I. Frank National University of Lviv, an exchange of research workers was possible (Hradecký, et al. 1999). Research of the alpine part of the Crimean Peninsula will continue buring the following years. The main sets of the research will be these thematic spheres: a detailed documentation of active faults, Quaternary tectonics and dislocations of river terraces and other Quaternary sediments, the creation of a digital model of the Crimean Mts. and a detailed morphostructural analysis of the evolution of the mountain landscape of the southern part of the Crimean Peninsula.

Key words: geomorphic evolution, the Crimean Peninsula

1. Geomorphology of the southern part of the Crimean Peninsula

1.1. Orography

The Crimean Mts., called Yayla in the crimean-tatar language, are situated in the southern part of the Crimean Peninsula and takes about one third of its area. The Crimean Mts. are formed by three prominently asymmetrical zones. Their southern and south-eastern slopes are noted for bigger slants than the northern ones. It reflects the basic morphostructural features of the territory.

The highest mountain range system by means of the steep southern slopes follows the shores of the Black Sea at a length of about 70 km. It reaches the maximum heights in its central part, where it culminates in the range of Babu-Ghan with the peak Roman Kosh (1545 m a.s.l.). Even the neighbouring massifs Chatyr-Dagh, Demerdzhy and

Yaltynskaya Yayla show similar hypsometrical conditions. The heights of particular massifs fall from towards the south-west and north-east to an elevation of 500–600 m a. s. l. The basic characterisation of the mountain range system is given by alternating long backs and extensive karst plateaus, which are mutually separated by deep valleys with mostly rocky slopes and lithologically contingent hollows with an intensively developed drainage pattern.

Both ranges lying north of the main system of the mountainous Crimea reach a lower elevation and have the character of cuestas with milder northern and north-western slopes. North of the main range there is situated the inner cuesta indicated as Predgornaya gryada reaching heights of 550–750 m a. s. l. of the elevation. It is a row of morphologically striking table rocks broken up by the deep valleys of the rivers Alma, Katsha, Salghir, Belbec etc. Mountains prominent in the relief are e.g. Chufut-Kale, Kaya-Tepe, Kaya-Bash etc.

The northern zone (the Outer cuesta zone) is continuous only in the western part of the mountainous Crimea north of the line of the towns Sevastopol-Simferopol. The elevation of this part does not exceed 350 m a. s. l. Owing to a small potential energy of the relief, particular ranges are here separated by widely opened shallow valleys. East of Simferopol they slowly pass to planes of the steppe Crimea.

The fluvial system of the mountainous Crimea in the south-eastern region is characterized by short consequent streams, which after several kilometres empty into the sea. Most of the rivers make then for the north and north-west of the main range of the Crimean Mts., from where they strikingly disperse in a excentric radial way and they intersect particular zones of the cuestas in deep fault-line gaps. The prominent drainage line of the territories, the Salghir river, empties into the Sivash Lake. At the western shore, the Belbec, Katsha and Alma rivers empty into the Kalamit Bay. In this way the main divide between the southern and northern part of the Crimean Peninsula is only a few kilometres from the edge of its southern shore.

1.2. Morphostructure

The morphostructural characteristics of the mountainous Crimea are given by the lithological and tectonic specifics of the area. Owing to a dense net of faults, the whole area is divided into an arranged system of blocks with the character of horsts. The hypsometric features of particular blocks are a direct reflection of neotectonic development of the relief, which reached maximum intensity at the turn of the Pliocene and Lower Quaternary (Judin, Gerasimov 1997, Varchusev 1997, Prášek 2000). The tectonic pattern of particular blocks is also given by an intensive closely folded and deformations of nappe, which preceded the proper neotectonic regime. Opinion the nappe pattern of the region originates in the newly accepted geodynamic model and the regional demarcation of particular nappes has not been finished yet. The nappe pattern is of the character of the mostly passive morphostructure and, in the present relief, it appears as anticlinoriums and synclinoriums. The particular horsts are mutually separated systems of the faults of both lengthwise and cross direction. The direction of the lengthwise faults is generally south-west to north-east, the cross faults are perpendicular to this direction. In this sense, the blocks of Chartyr-Dagh, Babu-Ghan and Demerdzhy stand out here individually. Within the framework of the morphostructures, it is possible to delimit areas with a relatively depressed position, which was caused by intensive denudational cutting of the more resistant Upper Jurassic limestones and by the disclosure of less resistant flysh rocks of the tavrida beds on the cores of old anticlinorias. A typical instance is the upper part of the basin of the Belbec, Katsha and Alma rivers (Katshinskye anticlinorium) and parts of the southern shore of Crimea (Yaltynskye and Tuakskye anticlinorium).

The attitude relations of rocks are supposed to be an important morphostructural aspect. In the Outer and Inner cuesta zones north of the main mountain range system, a typical relief of broken up structural tables with cuesta backs on tectonically less deformed the Cretaceous and Tertiary rocks are found here. In the highest mountain zone, the passive morphostructure presented by the attitude relation of rocks is removed by the longer – lasting denudation of the Upper Jurassic complexes. It becomes evident in the gradual relief of the highest ranges of Ay-Petri, Babu-Ghan, Chatyr-Dagh and further ones.

The specific morphostructures of the southern Crimea are the volcanic formations of the Middle Jurassic. Owing to the subduction of ocean's crust under the Crimean Peninsula the volcanic manifestations of andesite character appeared in Middle Cretaceous. A special case is the area of the mountain range Kara-Dagh, which is supposed to be the remains of a large stratovolcano. Effusive rocks selected from upper beds emerged here. An frequent manifestation of the Middle Jurassic volcanism is considered to be the intrusion in the form of laccolith penetrating through the Taurid formations. These structures are most widespread in the area between Alushta and Yalta (e.g. Kastyol, Ayu-Dagh, Thamny-Burun).

1.3. Karst

The phenomenon of the mountainous Crimea is the karst relief bounded by lithologically clear Upper Jurassic limestones. In this way the region of the Crimean Mts. with carbonates presents locations with specifically developed shapes of the relief. Even the younger sediments of the Cretaceous and Tertiary in the Outer and Inner cuesta zone (marlites, limestones, conglomerates) are subject to karstification. The process of karstification accelerates the system of faults and cracks on which the sequence of forms of exokarst and endokarst of reliefs is limited.

In this area, the plain type of karst is represented most and less then the karst of monoclinal ranges. The largest karst plateau is considered to be the Karabi Yayla lying in the eastern part of the mountainous Crimea. The medium elevation of the main plateau is about 1000 m a. s. l., the area of the plateau is about 200 km^2. West of the Karabi Yayla are situated Dolgoruckaya Yayla and Tirke, though not so large in area but with striking karst forms. South of them, the karst area Demerdzhy Yayla with less developed karst slopes on upper Jurassic calcareous conglomerates is situated. The northern plateau of the massif Chatyr-Dagh is a typical karst relief with cave systems. Even the highest areas of Babu-Ghan, Yaltynskaya Yayla and Ay-Petri are similar in character.

1.4. Sketch of denudation chronology

Except for the above mentioned structural factors, long-lasting erosion processes played an important role during the development of the relief. The result of their influence is the presence of three levels of piled surfaces – the Early Cretaceous, Miocene and Upper Pliocene ages (Lysenko, 1972, 1976). The Early Cretaceous piled surface is found in the largest area and also includes some particular karst plateaus. Its development is connected with the continental phase of the relief development during the stage of the affiliaton of the Crimea to Eurasia, the concomitant phenomenon is the primary phase of the karstification.

The regional differences of heights of this level are caused by neotectonic movements within the framework of particular blocks. Flat backs and plateaus in the highest part of the mountain system are said to be a typical instance of this level. The Miocene denudation level is of polygenetic character and its fragments are found mainly at the northern mountain base of the main back, where it debases Cretaceous and Paleogene sediments. Some residuum of this surface is found in many places owing to ferrous weathering crusts. The Upper Pliocene piled surfaces are found in quite large areas of the Outer cuesta zone, where they debase Sarmat formations with marlites, limestones, sandstones and conglomerates.

The development of today's river net may be dated from the Pliocene, at the time after the retreat of the Pont sea towards the north (Kljukin, 1978). In this period we can see the gradual extending of consequent rivers running from the rising mountain vault behind the shore line of the Pliocene sea. Rivers regressively cut into various cuesta zones and so numerous antecedent valleys arose. Such a character can be observed at valley parts of the rivers like Belbec, Katsha, Alma and Salghir, namely in the places where they intersect the particular cuestas. The pattern of the valley net making for the north to the Alminskaya depression and to the Indolsk-Kuban step fold is of a clearly radial excentric character. In place of the emptying of rivers into depressed areas, the depositing of large proluvial cones occurred. Some authors (Dobrovolskaja 1997, Embleton 1984) identify these accumulations with the landslide and deluvial-proluvial materials of the Masandrovskaya series in the southern slopes of the Crimean Mts. (largely surrounding the town of Yalta).

The denudation cycle is reflected itself in the development of the valley terraces of the rivers of the Crimean Mts. Kljukin (1978) dates the oldest terrace as from the period Upper Pliocene to the Early Quaternary. The Pleistocene terraces are represented by three levels, the youngest terrace level is formed by Early Holocene gravels. During the period of gradual vertical erosion in the course of the development of the terraces the horizontal displacements of beds and the disturbing of foots of slopes also appeared. This phenomenon is very striking by the rise of landslides in various levels of slopes of gaps going through the Outer cuesta zone.

The ages of the landslides may be dated according to their positions in particular terrace levels. On the basis of this statement we can distinguish between periods with higher landslide activity and periods of the stabilization of slopes. The period with the main stage of development of slope deformations goes back to the beginning of the Quarternary after depositing of the Upper Pliocene terrace grade.

1.5. Slopes

Slopes are the most active element of the relief of the Crimean Mts. Their character is given by structurally tectonic and lithological parameters (Photo 1). The slopes bound to more resistant formations of rocks (limestones, conglomerates, sandstone, marlites and vulcanites) are of the character of structural slopes, while those on little resistent flysh rock (e.g. Taurid formations) slopes have a prevailingly denudational character.

The structural slopes on limestones and conglomerates are of the character of rock faces and they are supposed to be the typical element of the relief of the border parts of particular Yaylas and northern cuesta zones. They are shaped by intensive mechanical weathering and by gravitional processes; this is often the question of original reshaped and partly recessive slopes. Various forms of gravitional deformations (gapping, rock-sliding, block slides) are considered to be a frequent morphological manifestation of these slopes (Photo 2). This characteristic can be found in southern slopes of the range steeply falling towards the shore of the Black Sea, which was originally predisposed by a system of lengthwise breaks. The southern and eastern slopes of Chatyr-Dagh have strikingly developed taluses at their feet. These indicate an intensive gravitational destruction of rock faces (Photo 3). On the eastern slopes of this mountain range (above the Angara pass) we examined gravitational fissures. Deformations of the gravitational type caused the gradualness of some slopes (for example the southern slope of the Northern Demerdzhy Mt., one with the fissures parallel with the incline of the slope played an important role here). The area of Kara-Dagh is considered to be an illustrative instance of slopes shaped by gravitational processes.

Erosional slopes are the dominant form of the relief of the territory raised by flysh rocks. One instance can be taken: the area of Katshinskye anticlinorium and the zone along the southern shore where little resistant flysh stands out. A dense erosional net (5–10 km.km^{-2}) with numerous landslides is a typical phenomenon here. Such a relief is soften of the character of the badlands, like e.g. on the shore between the towns Sudak and Kurortnoye, east of the town Alushta or west of the Chatyr-Dagh in the spring area of Alma river. The areally spread category of the erosional slopes are supposed to be abrasional cliffs.

The erosional network in little resistant flysh rocks in the shore zone is cut into a large foot area, which is of the character of a broken-up erosional glacis, about 10 km in width. The surface is solely bound to little resistant flysh rocks and ends at the foot of steep structural slopes made of limestones, conglomerates or volcanic rocks. On the surface of the glacis there are often scattered bulky tumbled blocks originating from higher parts of the slopes on resistant rocks. Many of them can be found several kilometres far from the source area and they even reach surf zones (the area of Kurortnoye), which indicates subrecent and recent retreat of structural slopes in semiarid conditions of the submediterrianean climate.

1.6. Fluvial landforms

The limiting factors from the standpoint of the development of the river net of the Crimea Mts. are geological conditions. The dense valley network on flysh rocks sharply contrasts with the less developed valley network on rocks of the carbonatic development. It is evident in the valleys of the northern shoulder, which copy the transversal tectonic lines in the direction of south-east – north-west. This is the question of deeply cut valleys with intensively passing vertical erosion. The existence of completely developed evorsion shapes in beds of rivers is one of the manifestations of vertical erosion. The giant potholes are peculiar in the water-course of the stream Auzuzen, which flows through the pass the Big Canyon. The depth of some potholes reaches as much as 2 m, the width is then from 3 to 4 metres. At potholes we found tectonic conditionality of their formations, when most of them are bounded to the crack system of the north-southern direction. In the water-course the evorsional shapes can also be formed in the levels out of the active reach of the running water, which indicates the speed of the proceeding vertical erosion.

Deep active gullets (ovrag) are considered to be specifically of the fluvial relief on flysh rocks and unreinforced slope sediments. In the territory between the seats of Kurortnoye and Solnetshnaya Dolina (the eastern part of the shore) a dense net of deep cuts, as a rule non watered, can be found. Some of them are almost of a canyon-shape character and their widths reach tens of metres. A typical feature of the cross profile of the largest rivers of the northern shoulder is the striking assymetry. It is caused by the folding of beds and by the following undercuting of valley slopes (Kljukin, 1978).

The arisen landslides caused the pushing-away of the streamline from the attached slope towards the opposite one. This phenomenon is most expressively seen in the opening parts of the valleys of the rivers Belbec, Katsha and further ones. Some parts of the main valleys are of the character of hollows with a wide valley bottom, which is the bearer of the signs of a prominent tectonic predisposition (e.g. the valleys of Angara and Salghir, south-east of the Simferopol). In these wide valleys we can find large terrace systems.

1.7. Specific features of weathering and surface degradation

Owing to the influence of specific morphoclimatical and lithological conditions numerous products of mechanical and chemical weathering have been observed. Some of them are of the character of microshapes on bare rocky outcrops, in other places they are seen as isolated rocks or rocky groups forming whole rocky towns. Some very bizarre shapes have developed on Upper Jurassic conglomerates of the south-western slopes of the Southern Demerdzhy Mt. (1239 m a.s.l.). The rocky town is of the character of typically rounded rocky towers, even several tens of meters high. The characteristic rounded shape of particular rocky posts is qualified by the character of the material (conglomerate). On some towers there are more resistant layers of conglomerate, which form shapes similar to rocky lids. Most of this towers are of the shape with an expressively wider base. The rocky towers occupies the part of the slope up to 850-900 m elevation, where their development was stopped by different lithological relations and by the maximum reach of the retrograde erosion (Photo 4). The original shape and the density of rocky forms were predestined by a dense net of cracks, which accompanies the Salghir-Oktyabrskyi fault zone. The directions 50°–230° (NE-SW), 166°–346° (NNW-SSE), 102°–282° (ESE-WNW) prevail.

A special regime of weathering and erosional processes gave rise to a strongly broken-up relief on the effusional rocks of Kara-Dhag. Here rocky towns appear on gravitationally destructed rocky slopes. It is not rare to find separated rocky pyramids, rocky gates and windows here.

It is still a question how much the processes connected with frost weathering have taken part in the modellation of the relief of the highest parts of the Crimean Mts. Some isolated rocky shapes bear signs of frost cliffs and of rocks destructed by periglacial processes. From the accessible climatic data and the morphology of the same parts, the possibility of the influence of snow-patch erosion processes till now may be deduced.

Owing to the gravitational permeation of some slopes we can localize areas with potential development of pseudokarst landforms in the Crimean Mts., e.g. the southern slopes of the Northern Demerdzhy and northern slopes of the upper plateau of Chatyr-Dagh.

2. Morphotectonics

2.1. Basic morphotectonic features

The mountains of the Alpine-Himalayan orogenetic system bear direct and indirect manifestation of active tectonic movements. The present-day tectonic movements are supported in the area of the Crimean Mountains by evidence of seismic activity. Earthquakes in the area of interest do not appear so often and have not such an intensity as in the surrounding active areas (Asia Minor, Caucasus, Balkan Peninsula) but stronger earthquakes became very expressively evident in the changes of the georelief. Seismotectonic and seismogravitational shapes of the relief are considered to be direct consequences of seismic activity. The dense net of lengthwise and cross fault lines, which predisposed the course of slopes and larger valleys played a dominant role during the neotectonic formation of the relief. The Crimean Mountains are generally of the character of a vault, which was tectonically broken into single horsts at the turn of the Pliocene and the Quaternary. The basic characterization of this vault is the absence of southern and south-eastern limbs, which reflects itself in the steep limitation towards the shore of the Black Sea. The vault culminates somewhere in the central part, where it reaches elevations over 1500 m. During the formation of the valley network and of some slope parts, fissure systems also played an important role. The morphologically most striking tectonic shapes of the relief appear in the areas of the layer surrounding the contemporary epicentres of earthquakes. The answer to the active tectonic movements is the increased dynamism of denudation processes. Some authors (e.g. Varchushev 1997) support the manifestations of the active tectonic by the development of endokarst landforms.

2.2. Geomorphological interpretation of faults

The basic morphotectonic manifestation of the area is supposed to be the direct relation between the tectonic lines and the spread of the same shapes of the relief. The breaks of the cross and lengthwise directions restrict the variously big segments of the earth's crust and in this way they give the Crimean Mountains a block-fault character. The cross tectonic lines mutually separate particular mountain groups (ranges), while the lengthwise ones qualify the inner differences of particular floes. One exception is the lengthwise fault zone, which follows the shore of the Black Sea and is connected with the subduction of the oceanic crust. This boundary line has qualified the steep southern limitation of the main zone of the Crimean Mountains and the Middle Jurassic intrusions of the vulcanic rocks are bound to it. The lengthwise fault zones are probably of an old character, the cross breaks activated themselves probably as late as during the neotectonic stage of the development of the relief. In places of the crossing of both directions, right-angled bends in the ground plan of the valley network and the increased intensity of the erosional processes often appear.

The cross tectonic lines strikingly qualify the linear shapes of the relief. From west to east, a striking rectilinear part of the shore between the town Sevastopol and the Saritsh cape and the valley of the rivers Tchernaya, Belbec, Katsha, Alma, Salghir and Angara. In the valleys making to the north-east from the Crimean Mts. to the area of the Indol-Kuban step fold, bends along the course of faults are not so expressive and fault zones predispose only some valley parts.

The manifestations of the cross segmentation are not too expressive in the south-western part of the main mountainous ridge. Particular mountain ranges like Ay-Petri Yayla, Yaltynskya Yayla and Babu-Ghan Yayla form a compact mountainous zone, and transverse faults are represented here by morphological manifestations of particular gaps among massifs. One example is the Gurzuf gap between the Babu-Ghan Yayla and Yaltynskaya Yayla. Morphologically, more striking cross faults have qualified the prominent mutual restrictions of particular mountainous massifs in the central part of the mountains, where they are connected with the existence of the Salghir-Oktyabrskyi fault zone. This fault system appears in a north-western direction near at the join of the towns Alushta and Simferopol each of which specifies two important earthquake areas – Yaltian and Alushtian. The sinistral strike-slip along one of the tectonic lines belonging to this fault system is striking too. Owing to this, the highest mountainous ridges are formed by Upper Jurassic limestones and conglomerates east of the join of the towns Alushta and Simferopol. Along way from the shore line, quite a wide zone of strongly broken-up relief on little resistant flysh rocks (Upper Triassic – Early Jurassic) is significant. In this way the change of the course of the shore south-westwards and north-eastwards from Alushta may be explained. South-west of Alushta the shore is of the general direction of south-west – north-east, while to the north-east, an east-north-eastern element prevails. The Salghir-Oktyabrskyi fault zone has qualified the rise of deep vallyes and ramp valleys among Babu-Gan Yayla, Chatyr-Dagh and the Demerdzhy group. The transversal faults played an important role during the upheaving of Kara-Tau above the Karabi plateau.

In the lengthwise fault lines we can see a slightly different morphotectonic manifestation. In contrast with the cross direction they are quite significant in the south-western part of the main zone. Particular mountainous ranges are prominently extended in the direction south-west-north-east here. The restriction towards the shore is striking here, on southern slopes of Ay-Petri conspicuously developed valley parts can be seen to follow this fault direction (Fig. 1), and, in the places of crossing with the breaks of the north-western direction, right-angled bends often appear. A typical instance is the area of the pass Big Canyon with a striking linearity of the valley and with right-angled bends in the directions of the tectonic pattern. The specific morphostructure is supposed to be a smaller horst of the Limen ridge westwards from the seat Simeiz at the foot Ay-Petri (Varchushev 1997). The back stretches from the shore in the southern direction toward the main ridge of Ay-Petri, from which it is separated by the grade bound to the lengthwise fault. The dense pattern of the longitudinal faults caused the segmentation of the back into the singular blocks. The ridge continue northwards from the coast to the main ridge of Ay-Petri Yayla, by which it is segregated by the rock step, which is determined by the longitudinal fault. The dense occurrence of longitudinal faults caused the segregation of the ridge into partial blocks.

The longitudinal faults caused the inner partition of particular higher mountain complexes. They have less activity in the south-western part of the mountains, for example, between this direction and the saddle Tshutshel, which is located between the peak of Babu-Ghan Yayla and the northern spur of the karst plateau (Sinap-Dagh with ground elevation Tshernaya). Longitudinal segregation are distinct in the groups Chatyr-Dagh, Demerdzhy, Tirke and Karabi. Chatyr-Dagh consists of two blocks, which are divided by a fault-slope on the longitudinal dislocation. A rock step divides the part of the mountain with its peak at 1,527 m a. s. l. and the northwards situated vast karst plateau

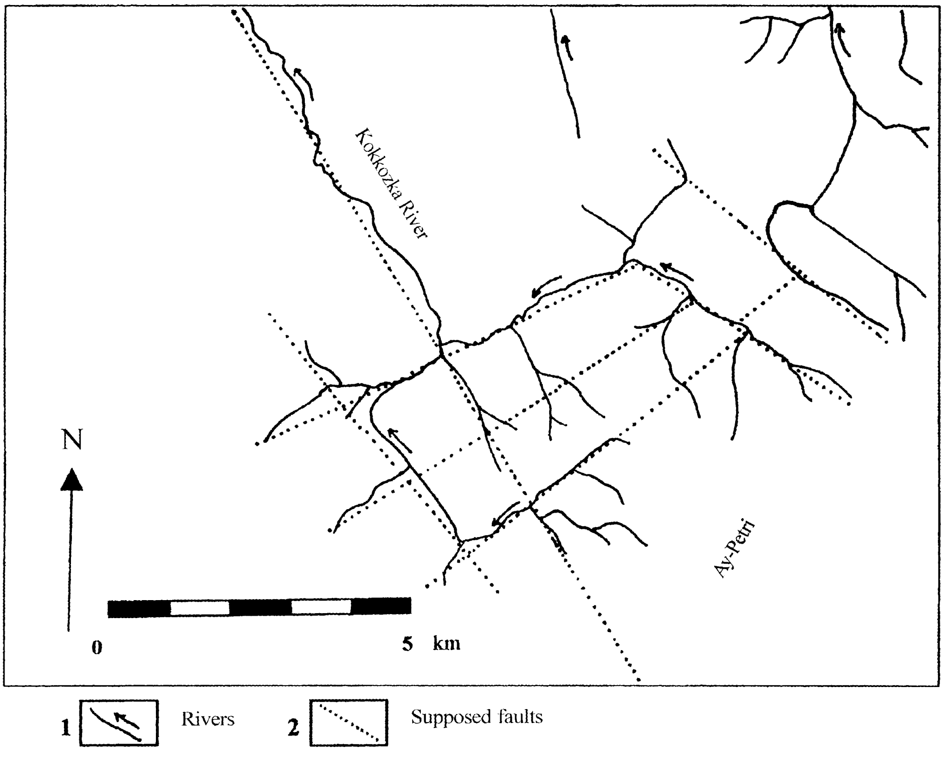

Figure 1: The drainage pattern in the northern slopes of Ai-Petri (the Balshoy Canyon area).

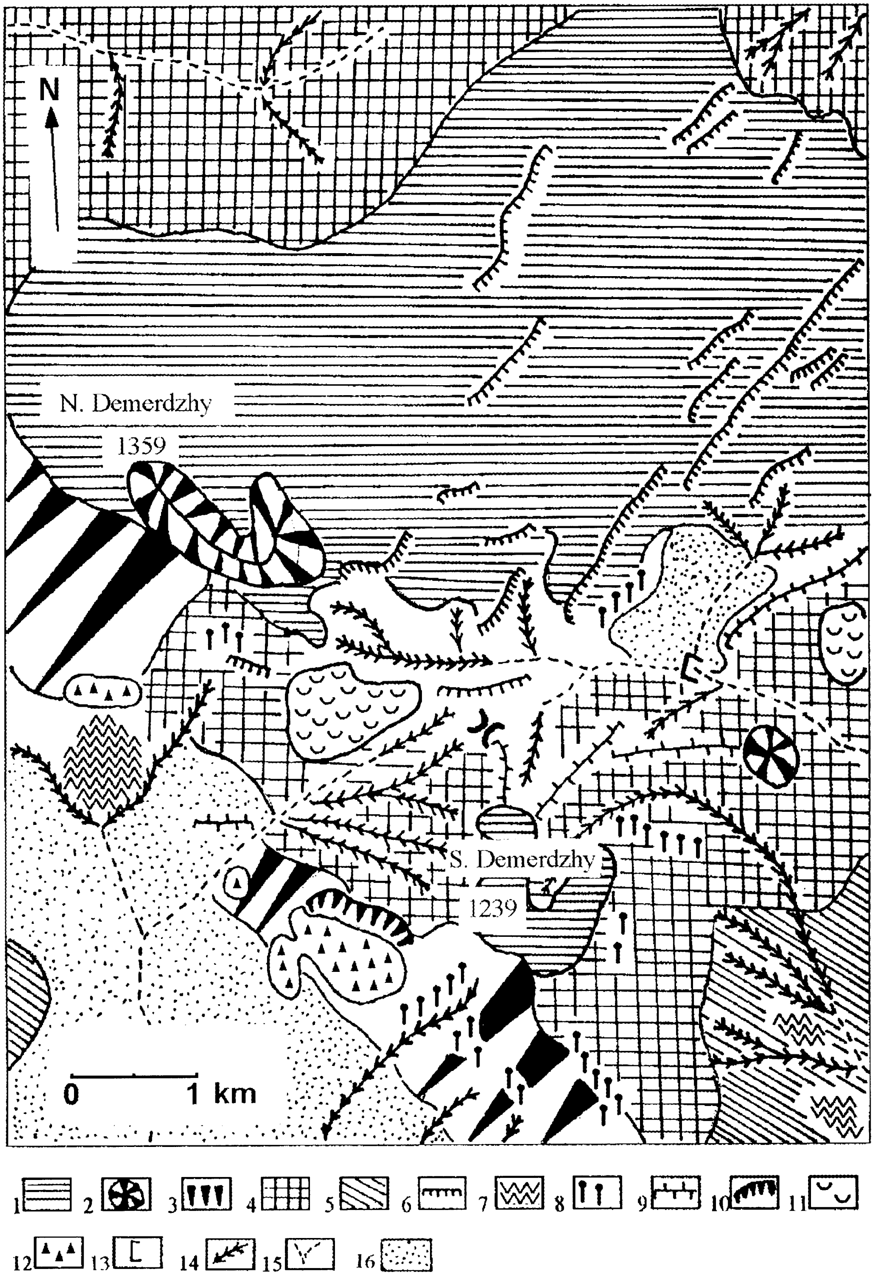

Figure 2: The field geomorphological sketch of the Demerdzhy Yayla.
1 – planation surface (karst plateau), 2 – necks, 3 – fault slopes, 4 – structural slopes on the Upper Jurassic limestones and conglomerates, 5 – denudation slopes on the Tavrida's Formation, 6 – faces of beds and cuestas, 7 – badland, 8 – castellated rocks in conglomerates, 9 – ridges, 10 – root areas of rock-falls, 11 – block landslides, 12 – deposition areas of rock-falls, 13 – waterfalls, 14 – gullies, 15 – river beds, 16 – foot slope debris.

at 1000 m a. s. l. The faultslope is about 3.5 km long and there are numerous evidences of gravitational gapping on it. The Demerdzhy group is divided by a longitudinal dislocation into two different complexes, Northern Demerdzhy (1,356 m a. s. l.) and Southern Demerdzhy (1,239 m a. s. l.), connected by the saddle Dzhurla. We can find similar examples in the Tirke Group, which is separated by a morphologically distinct rock step from the lower situated karst plateau Dolgoruckaya Yayla. The fault-slope is connected here with a linear extension, which had influenced a similar rock step in Chatyr-Dagh Massif. The continuation of this dislocation is the north-western part of Kara-Tau (1,220 m a. s. l.) towards the karst plateau Karabi.

2.3. Morphotectonic signs of the Salghir-Oktyabr fault system

The main fault system is the Salghir-Oktyabr fault (Photo 1 and 3). It stretches in a wide zone between the towns of Simferopol and Alushta and it is believed to continue to the Black Sea depression. There is a major area of earthquake epicentres of the Crimea Mts. along the fault belt.

The eastern slopes of Chatyr-Dagh and the opposite western slopes of Demerdzhy, Tirke and Dolgoruckaya Yayla are the morphological exhibition of the fault belt. The central depressed area is situated between these mountain units and tapers towards the Angara ghaut where it reaches its maximum altitude of 750 m a. s. l. East of the ghaut, towards the town of Alushta, the morphological confinement fades away, and the depressed area is of the character of denudation on weakly resistant flysh rocks. North-westerly, the most morphologically striking part of the depressed area between the northern karst plateau Chatyr-Dagh and Dolgoruckaya Yayla is the typical example of a ramp valley with a broad valley floor, bounded by remarkable fault slopes.

The eastern branch of the Salghir-Oktyabr fault system is parallel with the western slopes of Demerdzhy towards the north-west, where it shapes the western termination of Dologoruckaya Yayla. The western margin of Southern Demerdzhy Mt. is the 300 m high faultslope, heavily modelled by gravitational processes. The slope is distinctly modified by rock-sliding, which has been occurred during several periods, caused by bigger earthquakes in the years 1894, 1927 (two strong tremors in this year) and 1966. The least stable part of the slope there was affected by rock-sliding and the north-western part of a conglomerate rock city was totally destroyed. The area of the deposition of rock-sliding is formed by the rounded remains of downfallen rounded rock towers (Photo 4). The dimensions of blocks reach even as much as 12 x 14 size, the biggest them is 12 x 30 m. Ena (1987) describes several seismotectonic and seismogravitational segments on the western slope of the Southern Demerdzhy Mt.. He considers the root area of rock-sliding as a denude fault surface and he talks about the existence of the residuum of a little horst, confined by tectonic dislocations.

Towards the north-west the eastern branch of the fault system is morphologically evident on the western slopes of the Northern Demerdzhy Mt. (1,356 m), which was detached by the partial blocks of Pachkal-Kaya (1,137 m), Yuke-Tepe (931 m), Bal-Kaya (750 m) and Kyzyl-Kaya (738 m). The course of the fault slope of the Northern Demerdzhy Mt. is contrary to the western slope of the Southern Demerdzhy Mt. shifted about several hundreds meters to the north-east. An even a more distinct „joggle“ appears, if we compare the course of the fault slope of the Northern Demerdzhy Mt. with the location of the western slope of the Dolgoruckaya Yayla, where the difference is almost 2 km. The reason for „joggles“ is in horizontal dextral shifts on longitudinal faults. As for the Demerdzhy Massif, it is a tectonic line, passing through the Dzhurla saddle as for of the Dolgoruckaya Yayla, it occurred to shift on a morphologically distinct line on the northern rock step Tirke. The concurrent phenomenon of the neotectonic motion on the western slopes of Demerdzhy Yayla is a plastically distorted marginal parts plateau.

The fault slope, which confines Dolgoruckaya Yayla to the west, is morphologically evident in length of about 16 km and its height towards the north-west decreases from 250 m to 50 m a. s. l., near the village Ivanovka. The slope is segmented into a range of triangular shapes, which separate glens with very dynamic progress of vertical erosion and the development of slope failures. The longitudinal profile of these valleys have a gradation character. On the edge of the karst plateau above the fault slope, large caves are evolved.

By analogy we can describe the development of the opposite slopes, which confined the Chatyr-Dagh Group from the east. The morphologically evident fault slopes enclose from the east the upper and lower plateau, these slopes being damaged by numerous gravitational deformations. The southern part of the slope has a north-south direction. Near to the Kurulyuk-Su’s stream mouth to the Angara river (southwards to the Perevalnoe village) the course of the fault slope veers to the north-west. The north-western segment on this slope is a typical fault slope with small hanging valleys of the „wine glass“ type and subsided satellite blocks. To the south-west from the village of Perevalnoye, the margin of the karst plateau occurred to downthrow (a planed surface of the Early Cretaceous age) approximately about 100 m towards the ramp valley, watered by the river Angara. We can observe similar cases of the subsiding of the plateau margin on the western margin of the lower plateau Chatyr-Dagh, where they occurred to downthrow about 50 m towards the Kosa river valley (the dextral tributary of the Alma river).

2.4. Morphotectonic evidence on shoreline

The presence of neotectonics was identified in the eastern part of the southern coast, to the south-west from the village Kurortnoe. The tract of shore has the character of a gentle sloping foot surface of the glacis type (Photo 5), which originated on less resistant flysh rocks of the Late Jurassic age. The glacis is separated from the shore by almost upright cliffs close to 80 m high (Photo 6). To the north-west the surface originated on limestone klippes, which reach an altitude of about 400 m. On the glacis surface lies a layer of deluvial sediments with a thickness of about 5 m. It is a yellow-browny coloured sediment, distinctly contrasted with the dark flysh underlying rock. Sediments are characterised by the stratification with the interlaminating of loess foliums and attitudes of subangular limestone and slaty debris.

The foot glacis is divided in a transverse direction into vertical by differentiated blocks, separated from each other by clear straight slopes in a north-west direction. The relative height difference between the particular blocks is about 50 m. The articulation of the surface is probably connected with the existence of (geologically documented) transverse and longitudinal faults (Derenjuk 1984). The Quaternary vertical dislocation supports the presence of loess and deluvial sediments on the surface of particular blocks and the overall neanic foundation of the entire foot glacis.

Intense erosion processes, which proceed along the supposed dislocations are indirect evidence of recent active tectonics (Photo 7). The foothill of the rock steps trace several tens meters deep gullets and there are numerous products of rock-sliding. The size of limestone blocks reaches along the longer axe as much as 10 m.

3. Present-day geomorphic processes

The coast has a markedly structural character and it consists of steep Late Jurassic limestone cliffs, lying on top of soft flysh rocks. The most distinct sliding is founded in the coastal part of the Limen Ridge, which is an independent horst, relatively depressed against the main ridge of Ay-Petri Yayla. The longitudinal and transverse faults are remarkable in the relief, and their present activity of increased seismicity is documented (Varchusev 1997). From the direction of the main zone Ay-Petri, the ridge is broken into many blocks by longitudinal seismic dislocations, which initialised, together with the following tremors and abrasion, the breaking down of their part and falling into sea. The deposition area of the rock-sliding is formed by big blocks of limestones of several tens meters, distributed along the shore and the surf zone. The earthquake in the year of 1927 caused the rock-sliding on the western slope of the Limen structure, which destroyed the local sanatorium and a new several centimetres wide seismoclase arose on the slope above the sanatorium (Varchusev 1997).

Apart from the rock-sliding on the slopes composed of sedimentary rocks we can find in this area the same type of slope failures as on the Jurassic volcanite. The rock-sliding is the main geomorphic process of the slopes evolution in the Kara-Dagh area orientated towards the sea. It makes use of planes of weakness between particular layers of the effusive rocks.

A different form of slope failure on the rock massifs is bulging, caused by the unloading of slopes after tectonic movements and a successive intense deepening of valleys. The underlying flysh rocks play an important role. The superimposed blocks delve into the flysh and then move down the slope due to gravity. The results are fields of blocks with gapping tensile fractures in the upper parts of slopes (often on the ridges itself). The southern slopes of the Northern Demerdzhy Mt. are a typical locality, where massive blocks of conglomerates slip down by the subjacent Tavrid formations. The gapping of the coast part of the Limen Ridge near the town Simeiz is a more complicated example, where the role of seismic dislocations is important too.

The relief on less resistant soft flysh rocks is shaped by sliding. There are landslides with rotating slide surfaces here. They skirt the coast between the towns of Alushta and Feodosia. They evolve as a consequence of the abrasion of a shore zone and the intense ravining of a planation surface by the vertical erosion of intermittent streams. The accumulations of landslides reached sea level and the abrasion then conditioned the development of the cliffs. We often can observe the course of the slide surfaces in

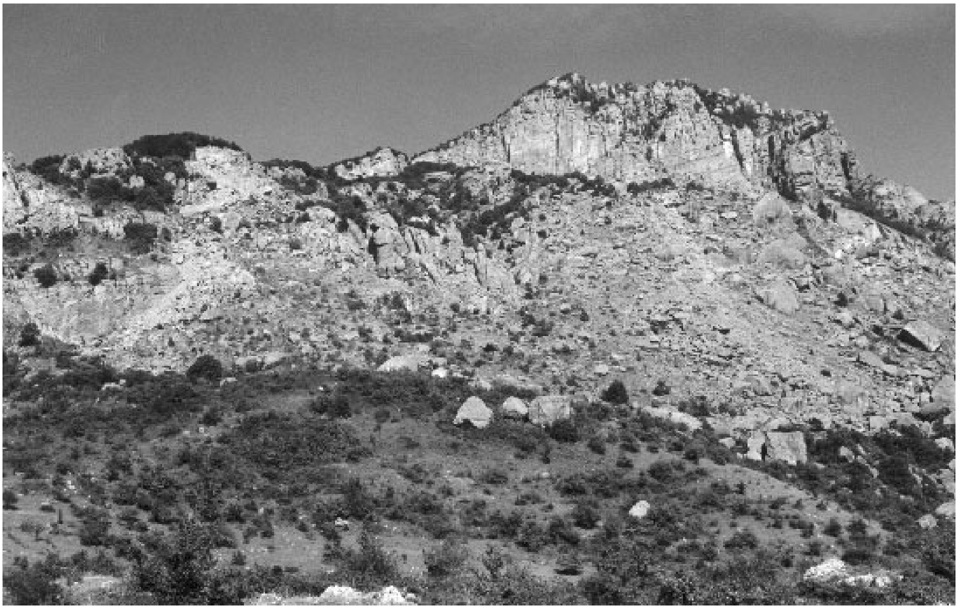

Photo 1: The western slopes of the Southern Demerdzhy (1239 m a.s.l.) are located on the eastern part of the Salghir-Octyabrskyi fault system. The rock-falls are typical on the fault slopes and in the northern part, a fault plain is supposed. (Photo by J. Prášek)

Photo 2: The area of accumulation of rock-fall products on the western slope of the Southern Demerdzhy. (Photo by T. Pánek)

Photo 3: The eastern marginal slopes of Chatyr-Dagh on the western part of the Salghir-Octyabrskyi fault. (Photo by T. Pánek)

Photo 4: Relicts of fallen rock towers by the foot of the western marginal slope of the Southern Demerdzhy. The largest blocks reach up to 30 m in the longer axis. (Photo by T. Pánek)

Photo 5: The accumulation part of a mud-flow on the shore to the south-west of the village of Kurortnoye. (Photo T. Pánek)

Photo 6: Actively developing cliffs on the shore between the villages of Kurortnoye and Solnyetshnaya Dolina. (Photo T. Pánek)

Photo 7: The pediment developed on less resistant flysh rocks to the south-east of the village of Kurortnoye which is divided into the individual blocks caused by recent tectonic movements along the north-western faults. (Photo J. Prášek)

Photo 8: The area of the badlands built by less resistant the Jurassic flysh rocks, located on the shore to the south-west of the village of Kurortnoye. (Photo T. Pánek)

profiles. The biggest concentration of landslides was documented to the south-west of the village of Kurortnoe (Photo 5). The length of these landslides is almost to 100 m and the height of root area margins reach even 50 m. The active evolvement of landslides is instanced by the cover of accumulations on subrecent alluviums of rivers.

A considerable amount of mass is transferred by landslides. This material is the product of the rock-sliding at the joining of the foot surface with the limestone nappes. Even blocks weighing a couple of tons are displaced, and are uncovered by abrasion in the deposition areas of landslides. Of geological interest in the Kurortnoe surroundings is the occurrence of conglomerate intercalations, which are lithologically distinctly different from the clayey rocks. These conglomerates often contain olistostrome of the Paleozoic age (Muratov 1960), which originated upon the formation of the margin of the sedimentary basin in the Triassic and Jurassic period. They are often found in bare depositional areas of landslides.

The depressed areas of the Tavrid formations belong to the landslide regions too, for example, the Katsha anticlinorium, to the west from Chatyr-Dagh. Large landslides were observed even on the margin of the fill terrace of the Angara river, about 1 km to the north-east from the village of Perevalnoe. It is necessary note the occurrence of torrents of mud, documented to the south-west from the village of Kurortnoe (Photo 5).

We documented the most distinct evidences of erosional processes on flysh rock slopes, where sheet-wash, runnels and gullets were observed. A major factor of erosional acceleration is the human disturbance of vegetation. The rapid transport of intermittent gullet-beds, watered only during flurries is documented by big subangular block of resistant rocks.

A widespread element of the relief on bare outcrops of less resistant rocks is remodeling by erosion into a surface of the badlands type. Determinant preliminary processes for the development of the badlands is the destruction of coastal slopes by abrasion and origin of landslides (Photo 8). The upcountry landscape is ravined by the vertical erosion. New slopes are then exposed to dynamic erosion. The remains of the original surface rise above the newly formed surface as knobs. Sheet-wash and the initial stages of erosion conditioned the evolvement of the earth and rock pillars, not only on bare flysh, but also on the tuffs of the Kara-Dagh masiff. Numerous earth pillars have evolved on the slope mass at the foot of the Southern Demerdzhy.

A significant geomorphic factor is sea abrasion. The intensity of the abrasion is given by the character of the rock environment. The abrasion processes can be evaluated by the character of cliffs, which evolve as a consequence of the action of the waves in the surf zone. The most distinct cliffs are developed on coasts formed by flysh rocks and on more resistant massive rocks the shore slopes keep their structural features. Indirectly, the abrasion can cause the acceleration of slope failures here, e. g. in the area of the rock-sliding near the town of Simeiz.

We documented the evolvement of cliffs at the part of the shore between the towns of Alushta and Feodosia in the locality Kurortnoe-Solnyethnaya Dolina. The cliffs reach a height of up to 100 m here. Abrasion has shaped the foot of the slope to a height of about 10 m. The active recession of cliffs happens during thunderstorms, which is exemplified by a higher coastal bench, compounded of bigger, less sorted gravel material, which lines the foot of the cliffs. The bare flysh rocks, exposed to the disintegration and decay by sea water, are mouldered, and so more subject to the effects of erosion and slope failures.

The subsurface forms of the removal of the insoluble rocks and their morphological sequels are typical for previous loose rocks with a wide variety of grain-size. The finely granular, clayey and silty particles, were removed in this process, whereas the bigger fractions or blocks remained in situ. The result is the development of caves and surface subsidence. The well developed subsurface erosion forms occur at the sides of the cliffs near the village of Kurortnoe. There is a thick bed of a previous deluvial material (limestone debris with loess admixture with typical prismatic jointing) lying on the waterproof flysh rock here. Caverns on the margin of the 100m high cliff developed, which, after the following inbreaks, dismembered the surface into the bizzare shapes resembling rock cities. The morphologicaly different depressions of the subsurface erosion evolved on the surface of the foot pile (Funa Bastille) below the western slope of the Southern Demerdzhy Mt. As well as depressions, there are many gaping fissures, indicating of the subsurface removal of fine granular particles among the bigger blocks of the older sliding origin.

One of the dominant processes in the development of landforms in the limestone areas is dissolution by water. This process is accelerated in the Crimea Mts. by an extensive deforestation of partial mountains and by the presence of chemically pure limestones. The evidence of this process are microshapes on bare rocks, i.e. karrens and solution pits. The depositional areas of rock-sliding near the town of Simeiz are totally karsted. A well-developed indentations due to solution of material of the size even 0.5 x 0.5 x 0.1 m on the surface of downfallen blocks was observed together with developed outflow grooves.

Quite a special category of the karst relief processes are the gravitational movement of masses in the subsurface caves. Some authors consider the sudden rock fall of a cave roof with the secondary sinter filling as evidence of older seismicity (Solomatin 1997). For example, in the Krasnaya Cave in Dolgoruckaya Yayla he describes warped blocks of a roof hefting 43 tons. We observed the warped blocks of the cave roof in the Mramornaya Cave of the size of tens of meters along the longer axis.

There is a long-term human influence in the region of the southern Crimea. First, the heavy intervention of human beings on the landscape hung together with the ancient colonisation of the territory. At that time, extensive deforestation occurred. It preceeded an increased intensity of erosion and karst processes. An important chapter is the relationship between society and the landscape during the totalitarian Soviet regime. The negative relationship with the landscape exerted in the Soviet era continues. The distinct human impact on the landscape has been increased by construction since the disintegration of the Soviet Union. A frequent phenomenon is the construction of new housing estates for tatarian repatriants and the foundation of large buildings on the coast. The morphological location and the foundation of these buildings are often wrong. Especially endangered ones are those founded on landslides. An attempt to reaf forest some parts of the karst terrain on the gradual terraces of slopes is interesting. This way distinct landforms arise. We saw, that most of the attempts were not successful.

4. Conclusion

The first stage of the geomorphological research of the alpine part of the Crimean Peninsula brought these results:

1. We obtained information about some new views on the geodynamic development of the southern part of Crimea. The work of Judin and Gerasimov (1997), which arose from the theory of plate tectonics, appears to be basic. The tectonic pattern of the Crimean Mts. is connected with the subduction processes on the active margin of the Eurasian plate, roughly from the Middle Jurassic. The Crimean Mts. obtain their basic hypsographic features through the most intense neotectonic movements, which came through on the boundary of the Pliocene and the Quaternary. Recent tectonic movements are instanced by an active seismic activity due to the quasisubduction of the oceanic crust.
2. The Crimean Mts. got their basic structural features before the Late Alb, however the finishing of the detailed articulation and separation of partial plates, including of tectonic activity on the main fault belts, is the Cenozoic age (most scientists consider it to be of Eopleistocene age).
3. It is proved by geodetic measurements, morphologically and seismically, that tectonic movements of vertical and horizontal directions continue and they support the theory of the quasisubduction of the suboceanic crust. The size of the movements is about a few millimetres per year. It happens to the periodic turn of elevations and falling of partial blocks at the general upheaval of the central part of the Crimean Mts.
4. During the geomorphological development, the area of the Crimean Mts. have obtained the shape of a vast, inner differentiated vault, which is strictly assymmetric as a consequence of the absence of a southern limb. During neotectonic activity the stage vault was split in to the partial blocks, which have basically the character of horsts.
5. The most distinct effects of the morphotectonics were documented in the area of the Salghir-Oktyabr transverse fault belt. The chain, crossing this belt, is corrupted to a distinct depression, which has the character of a ramp valley. The active epicentres of earthquakes along the Salghir-Oktyabr fault belt can be documented by intense slope movements. The active tectonics is pronounced in the south-western part of the Crimean Mts. and along the Black Sea coast.
6. The slide failures have a different character on massive rocks and on soft, plastic flysh sediments. The structural and fault slopes of the highest ridges are distorted by rock-sliding and various types of block slides with the presence of an active tectonics. In the flysh area (for example the Tavrida formation) there is, as the main factor affecting landslides, the position toward the streamflow lines and the activity of abrasion in the shore zone.
7. The main difference in the activity of erosion processes was observed between the areas composed of resistant flysh rocks and the parts of the mountains, which created previous strongly karsted formations. The dense erosion pattern on flysh is formed as deep and active gully, on their slopes the development of badlands recently happened, for example the strongly erosional gullying of area – vast foot glacis, can be observed between the towns Alushta and Feodosia.

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GEOMORFOLOGICKÝ VÝVOJ A SOUČASNÉ GEOMORFOLOGICKÉ PROCESY V JIŽNÍ ČÁSTI KRYMSKÉHO POLOOSTROVA (UKRAJINA)

Résumé

Krymské pohoří v jižní části Krymského poloostrova je tektonicky aktivní morfostruktura s vysokou dynamikou vývoje reliéfu, včetně rozsáhlých sesuvů a intenzivního vývoje erozních tvarů. Hlavním cílem výzkumu byl geomorfologický průzkum a vytvoření databáze pro geografický informační systém. Podrobně byly dokumentovány aktivní zlomy, kvartérní tektonické dislokace říčních teras a dalších kvartérních sedimentů. Dále byl vytvořen digitální model reliéfu Krymského pohoří a byla provedena podrobná geomorfologická analýza vývoje povrchových tvarů jižní části Krymského poloostrova.

Tektonická stavba Krymského pohoří je spojena se subdukčními procesy na aktivním okraji Evropské desky přibližně od střední jury. Hlavní orografické rysy tohoto pohoří vznikaly během nejintenzivnější etapy neotektonických procesů na hranici pliocénu a kvartéru. Recentní tektonické pohyby doprovází seismická aktivita způsobená quasisubdukcí oceánské kůry. Gedetickými měřeními, geomorfologicky a seismicky je prokázáno, že pokračující tektonické pohyby mají velikost několik milimetrů za rok.

Nejvýraznější projevy morfotektoniky byly zjištěny v oblasti Salghyr-Oktjabrského příčného zlomového pásma. Hřebeny jsou brázděny nápadnou depresí, která má charakter visutého údolí. Aktivní epicentrální území zemětřesení podél tohoto zlomového pásma jsou indikovány také intenzivními svahovými pohyby různého typu na masivních, resp. plastických horninách. Ve studii je též popsán specifický soubor erozních tvarů horské a pobřežní části Krymského poloostrova.