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Landslides and debrisflow processes of the Mangyshlak Peninsula

The zones of episodic, hydroclimatically triggered, high-mobility landslide and mudflow processes in Mangyshlak span multiple geomorphological settings. These include the Ustyurt Escarpment and adjacent isolated “island” plateaus, the foothill areas of the escarpment, peripheral zones of the peninsula’s low-mountain structures, coastal cliffs along the Caspian Sea, and the flanks of large depressions within the low-lying plateaus. The most prominent landslide complexes occur along the southeastern cliffs of the Karagiye Depression and the northern cliffs of the Tyub-Karagan Peninsula (particularly the massive Zhygylgan landslide complex). Primary mudflow activity is concentrated within the western valley systems of the Mangyshlak Peninsula and the northern valley networks draining into the Karagiye Depression. Orographically pronounced morphological complexes were predominantly formed during the Middle Pliocene, as evidenced by Akchagylian deposits abutting Mangyshlak’s coastal formations. The episodic occurrence of highly dynamic landslide and debris-flow processes spans several geomorphological settings across the Mangyshlak region [1, 2].

Keywords: Landslides, debris flows, Mangyshlak, Tyub-Karagan, Karagiye Depression, Khvalynian marine terraces.

Introduction

The current climate conditions in the low-lying desert periphery of the Mangyshlak Peninsula—where annual precipitation ranges between 140–160 mm—might appear insufficient to trigger widespread modern landslide and debris flow activity. However, irregular heavy downpours and long intervals between years with relatively heavy precipitation change the picture. For example, during the summer months of 1965–1967, heavy downpours in the mountainous part of the peninsula (the Karatau and Aktau ranges) mobilized large volumes of loose mass accumulated due to weathering and “generated” extended mudflows that flowed along usually dry valleys into the lowland frame of the mountains [3]. Concurrently, the replenishment of aquifers led to increased landslide activity.

The episodic occurrence of highly dynamic landslide and debris flow processes spans several geomorphological settings in Mangyshlak. These include the cliffs of Ustyurt (along with neighboring “island” plateaus) and their foothills, the margins of the peninsula’s low-mountain structures, the Caspian Sea cliffs of Mangyshlak, and the slopes of large depressions that disrupt the surface of low plateaus (e.g., Karagie). The boundaries of hypsometrically low plateaus, table-top elevations, structural-denudation plateaus, and coastal lowlands often feature complexly constructed ledges—steep, near-vertical cliffs reaching heights of hundreds of meters. They arise in the presence of stable armor layers of Neogene limestones, under which easily destroyed loose rocks lie. The cornices of the cliffs usually hang over the steep slopes, because of which the prerequisites for large-scale gravitational processes are created [4, 5]. Meanwhile, the narrow floors of erosional valleys, deeply incised into the plateau retain in their microrelief morphological traces of the descent of extended mudflows.

Materials and methods

During the Kazakh Russian geoarchaeological expedition to the Mangyshlak Peninsula from April 10 to 25, 2024, and the subsequent processing of the collected materials, the following methods were used. Field-route studies of key areas most prone to landslides and mudflows, analysis of specialized literature combined with the interpretation of remote sensing materials from different years, dating Pleistocene and Holocene loose sediments using optically stimulated luminescence [6].

Results and Discussion

The formation of most closed depressions on the South Mangyshlak plateau, including the deepest deflationary depression in the CIS—the Karagiye Depression (-132 m)—began during the pre-Akchagyl period and is linked to karst processes. These processes eroded the armored Neogene (Sarmatian) carbonate rocks in the crest of a secondary anticline (“swelling”) on the southern flank of the large Beke-Bashkuduk anticline, exposing rocks susceptible to weathering and deflation. The primary deepening of the depression was driven by arid denudation agents in the second half of the middle Pliocene. The depression underwent its most significant deflationary deepening during the xerothermic pre-Khvalynsk epoch. In the late Quaternary, the Khvalynsk transgression reached its maximum, depositing terraces along the depression’s margins with elevation markers at +20 m (corresponding to the coastline of the Buinaksk stage of the Early Khvalynsk) and -10 m (the Sartas coastline of the late “Khvalynsk”) [7].

In the absence of a permanent surface runoff today, periodic mudflows “flow” into the Karagiye cryptodepression (Southern Mangyshlak) along two complex systems of dry valleys with a southwestern orientation. These valleys originate on the Karatau Ridge and cross the Southern Aktau Ridge via narrow transverse valleys. The Northern Aktau Ridge is dissected in several places by through valleys known as “kalas”, which have incised into the deluvial-proluvial deposits and occasionally channel runoff from the Karatau Depression in the form of short-lived, violent mudflows [8, 9].

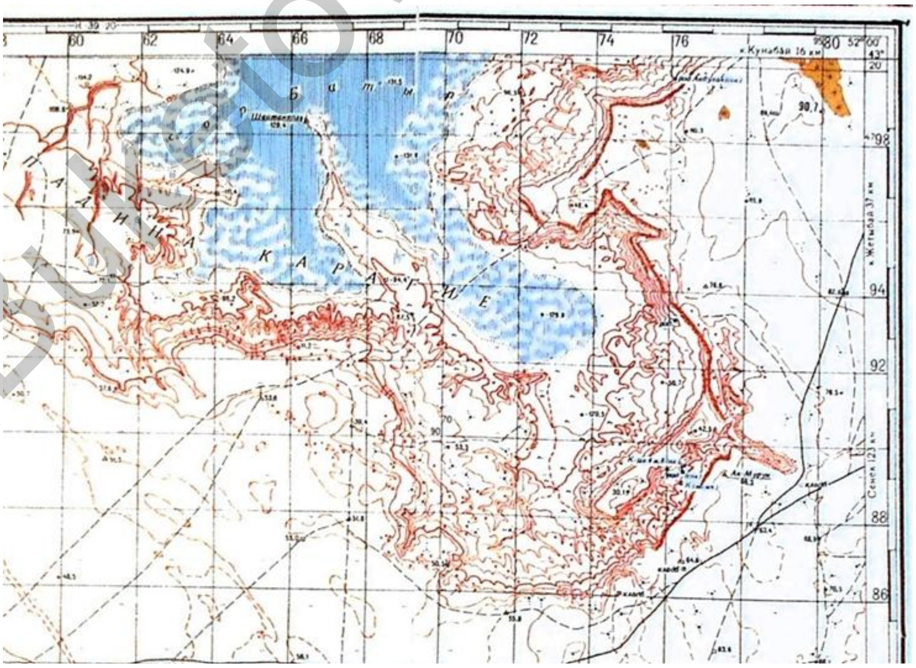

Figure 1. The southeastern margin of the Karagiye depression,
showing the maximum extent of post-Khvalynsk landslide displacements.
Original map scale 1:100000

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During the Khvalynsk transgression, the climate of Mangyshlak became colder and wetter than in the preceding period, leading to significantly increased erosional activity [10]. The Upper Pleistocene erosional valleys are now inherited by an open network of modern, predominantly dry valleys. Available evidence suggests the last significant climate humidification in the region occurred between the 24th and 12th centuries BC, which can be correlated chronologically with the first of the "New Caspian" periods of increased humidity [11]. Modern mudflows, which are rare, are considerably smaller in scale compared to those of the "early Caspian" period.

One of the most prominent landslides formation zones in the eastern margin of the Karagiye depression. Here, landslide blocks measuring up to 2 km width and extending along slopes for distances of up to 1600 m and situated beneath the scarps of Khvalynsk terraces, where they overlie proluvial trains [12] (Fig. 1).

Even more extensive landslide deformations occurred along the northern cliffs of the Tyub-Karagan Peninsula, situated near the neo tectonically active Mangyshlak Trough [13]. Here lies one of Kazakhstan's largest long-distance landslide complexes—Zhigylgan. With a frontal width of 3 km, the landslide "tongue" extends for 5 km, protruding 3 km into the northern Caspian Sea (Fig. 2). The crest of the collapse scarp reaches a height of 155 m, resulting in a total elevation drop of over 190 m down to the shallow sea.

Figure 2. The giant Zhigylgan (fallen earth) landslide complex on the northern cliffs of the Tyub-Karagan Peninsula. Massive Sarmatian limestone beds are part of a large-scale landslide displacement, with a vertical drop exceeding 190 m. Photo by A. Lukashov.

Morphological traces of past large-scale mudflows are most clearly visible in the western part of Mangyshlak, particularly along the valleys of Ashiagar, Tulkili (Fig. 3), Shakpat-ata, Kyzyl-Ozen and several others. The modern floors of these dry valleys are characterized by longitudinally oriented ridges of unsorted material, where semi-rounded fragments of carbonate rocks are embedded in a silt-sand matrix. Post-mudflow floods incisions are scarcely discernible, having been partially smoothed out by aeolian processes.

Figure 3. Typical mudflow microrelief on the floor of the Tulkili Valley,
near the southern coast of the Tyub-Karagan Peninsula, 1.6 km north of Cape Segendy. Photo by A. Lukashov

Mudflow morpholithogenesis serves as an episodic geomorphic mechanism in Mangyshlak. Fluctuations in the Caspian Sea levels appear to have no significant impact on mudflow activity. Furthermore, within late Pleistocene and Holocene transgressive deposits, there occur interbeds and lenses of poorly sorted sediment that exhibit morphological similarities to mudflow facies (Fig. 4).

Figure 4. Mudflow facies inclusions within sandy-clayey sediments, overlain by aeolian deposits from the middle phase of the early Khvalyn transgression, on the left bank of the Kyzyl-Ozen valley in the southern of the Tyub-Karagan Peninsula, 3 km from the coast. Photo by A. Lukashov

Conclusion

Hydroclimatic factors during the late Pleistocene and Holocene, combined with the lithology of Mangyshlak coastal zones, contribute to the episodic activation of landslide and mudflow processes. The irregularity of atmospheric moisture input and the high efficiency of physical weathering (thermal and insolation) result in the intermittent mobility of weathered lithoflows, exhibiting both relatively compact and linearly oriented distributions. The prevailing aridity ensures long-term preservation of the resulting morphological complexes by limiting water and wing erosion. Large landslide formations exhibit horizontal extents

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on the order of kilometers, with vertical relief differences reaching several tens of meters. Mudflows can extend for tens of kilometers, with channel widths of tens of meters and deposit thicknesses of several meters.

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Маңғышлақ түбегінің көшкіндері мен селдері

Маңғышлақтағы жоғары серпінді көшкін және сел процестерінің эпизодтық (тиісті гидроклиматтық алғышарттарды жүзеге асырумен) пайда болу ареналары бірнеше геоморфологиялық жағдайларды қамтиды. Бұл ең алдымен, Үстірт жартастары (сонымен қатар көрші оқшауланған «аралдық» биік үстірттер) және олардың етегі, түбектің аласа таулы құрылымдарының шеткі бөлігі, Каспий теңізінің Маңғышлақ жартастары, аласа таулы үстірттердің бетін күрделендіретін ірі ойпаттардың бүйірлері. Ірі көшкіндердің локализацияланған аймақтарының ең жарқын мысалдары Қарақия ойпатының оңтүстік-шығыс жартастары, Түпқараған түбегінің солтүстік жартастары, атап айтқанда, Жығылған көшкін кешені. Негізгі сел аймақтары: Маңғышлақ түбегінің батыс бөлігінің аңғарлары және Қарақия ойпатының солтүстік-батыс бөлігіне ашылатын аңғарлар жүйелері. Орографиялық жағынан ең қарама-қарсы морфологиялық кешендердің — аталғандардың ішінде қалыптасуы негізінен орта плиоценде болғаны белгілі. Бұған Ақшағыл кен орындарының Маңғышлақ жағаларымен іргелес болуы нанымды дәлел.

Кілт сөздер: көшкін, сел, Маңғышлақ, Түпқараған түбегі, Қарақия ойысы, Хвалынск теңіз террасалары.

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Оползни и сели полуострова Мангышлак

Арены эпизодического (при реализации соответствующих гидроклиматических предпосылок) протекания высокодинамичных оползневых и селевых процессов на Мангышлаке охватывают несколько геоморфологических обстановок. Прежде всего, это чинки Устюрта (а также соседних изолированных «островных» возвышенных плато) и их подножия, периферия низкогорных сооружений полуострова, Мангышлакские обрывы Каспия, борта крупных впадин, осложняющих поверхность низменных плато. Наиболее яркие примеры районов локализации крупных оползней: юго-восточные обрывы впадины Карагие, северные обрывы полуострова Тюб-Караган, в частности, гигантский оползневой комплекс Жигылган. Основные ареалы проявления селей: долины западной части полуострова Мангышлак и системы долин, открывающихся в северо-западную часть впадины Карагие. Известно, что образование орографически наиболее контрастных — из перечисленных — морфологических комплексов происходило в основном в среднем плиоцене. Об этом убедительно свидетельствует прислонение акчагыльских отложений к берегам Мангышлака [1-2].

Ключевые слова: оползни, сели, Мангышлак, полуостров Тюб-Караган, впадина Карагие, хвалынские морские террасы.

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