ELSEVIER

Geography and Natural Resources 30 (2009) 156–160

GEOGRAPHY AND NATURAL RESOURCES

Geomorphological features of the Western Tien Shan

G. F. Ufimtsev *

Institute of the Earth's Crust SB RAS, Irkutsk

Received 15 September 2007

Abstract

The morphological features of the relief of the Western Tien Shan are outlined. It is pointed out that the high-altitude belt of the alpine relief is home not only to relicts of pre-orogenic planate surface but also to relicts of glacial planation surface, and to exposured weathering fronts. The relief of submontane belts with arid morphosculpture, and with the occurrence of local near-valley planate surfaces is described.

Keywords: peneplain, weathering front, equiplain, adyr, Tien Shan.

Introduction

Since the time of P. P. Semenov's travels (later on, Semenov-Tyanshansky) the Tien Shan has remained one of the most attractive objects for scientific enquiry among national geographers – glaciology and young tectonics and seismotectonics, and high-altitude zonality of the mountain relief with the whole of its diversity render these mountains an ideal research site. It is not accidental that many researchers engaged in the study of the natural environment and entrails of the Tien Shan are intuitively led to conceive the idea of self-sufficiency of these mountains and devote their whole career to their study [1, 2]. It is the Tien Shan that came to be the research site where the theory of neotectonics emerged [3], which occupies a prominent place in the system of geotectonic concepts.

At the present time, the Tien Shan as the object for study is the most attractive from the following considerations: firstly, it is the scene of collocated, closely interwoven, different types of mountain morphogenesis (Alpine-type, arid, under the ice, and Siberia-type); secondly, this mountain massif abounds in geomorphological natural monuments, and, thirdly, the relief of the Tien Shan differs from the other mountains of Eurasia in special elements of morphological landscape [4-6]. They include peneplanation planes (regional and local), characteristics of the morphosculpture of the slopes in the Alpine-type zone that are caused by the activity of snow avalanches, szyrts (wide and narrow morainic depressions in the high mountains), and adyry (low foothills) imparting a clearly pronounced individuality to this highland.

The pre-orogenic peneplanation plane

In most publications on geomorphology and neotectonics of the Tien Shan, the pre-orogenic peneplanation plane (Late-Mesozoic peneplain) is commonly accepted as one of the main elements of morphological landscape of these mountains [1-3]. Indeed, in the near-top zone of the side arms of the mountain ranges with no Alpine-type forms present, we observe flattened surfaces, as though they were diving underneath the Cainozoic sediments of the hollows and serving as the basal surface. This ancient surface often supports also Jurassic deposits, including within the mountain ranges [3]. Sliding of the denudation plain on Jurassic sediments and its smooth outcropping to its basal surface of these sediments appears to indicate that the pre-orogenic peneplain organically includes also the bare areas of the pre-Jurassic denudation plain.

The morphogeological structure of the pre-orogenic peneplanation plain on the Tien Shan is poorly studied. It is also neglected that the peneplains, as they are nearly plains, are not able to take over basin sediments [7], because, to do so, the relief must experience additional planation. It is therefore necessary to pay attention to the structure of the relief of the areas where the pre-orogenic planation underwent

* Corresponding author.
E-mail address: ufim@crust.irk.ru (G. F. Ufimtsev)

doi:10.1016/j.gnr.2009.06.012

outcropping from beneath the mantle of Cainozoic deposits. Such a situation occurs in the marginal parts of intermontane depressions that underwent inversional uplift and transformed to piedmont adyry-ridges.

Areas of the bare basal surface are outcropping from beneath the mantle of Cainozoic deposits occurring above Paleozoic granites, on the northern shore of Issyk-Kul in Urochishche Turaigyr on the inner ridge of piedmonts. This place is dominated by the complicatedly structured hillocky terrain microrelief with changes in relative altitudes of a few meters. Its component landforms are all arranged chaotically, so that such a surface can no longer be assigned to the category of peneplains. The pattern of the microrelief suggests that, along with Cainozoic deposits, the ancient weathering crust was eroded, which consolidated the weathering surface. In consequence of this, the surface of the ancient weathering front was exposed. Features of this kind have received a specific terminological designation, namely, the etchplains [8].

Another place where the ancient weathering front appears to be exposed, is represented by the northern side of the small Kyzyloiskaya depression within the Kekermeren river basin between the Dzhumgal and Susamyr mountain ranges to the south of the city of Bishkek.

Glacial steps and peneplanation plains

In the high-mountain parts of the Tien Shan ranges, especially on their northern and northwestern slopes, flattened subhorizontal and gently sloping steps of different size can be found (Fig. 1), which appear to undercut from above the crests of the spurs, including the remains of the pre-orogenic planate surface. Furthermore, they are surrounded by or adjacent to Alpine-type high mountains. The near-top steps (of a different morphology) may well be grouped together into genetic series of transformation (see Fig. 1), the initial element of which is provided by the bottoms of the hanging cirques and glacial cirques with destroyed sides. If the bottoms of the neighboring troughs are merged together, the step expands to become a planate suprabase surface. With a further expansion of these features (let us call them the glacial steps), broad planate surfaces are generated; they produce in the near-top zone of the mountains a peculiar stage of relief which can dissect the Alpine-type highland into separate massifs. Doubtlessly they are rather interesting forms of glacial planation which on the Tien Shan occupy the near-top parts of the windward and, accordingly, humidified slopes of the mountain ranges. Being suprabasal peneplanation plains, they are, to some extent, similar to altiplanation surfaces, and with the arms of the spurs (with a resemblance of their positions in the structure of morphological landscape).

In the Tien Shan mountains, traces of glacial reworking of the relief are also seen in the intermontane depressions. A characteristic attribute of such depressions is provided by the Arabel szyrt located at altitudes of about 3700 m, along the southern slope of the Terskei-Alatoo range. Configured as a bell-shaped expansion, the szyrt connects with the valley head of the Sary-Moinoke, the right-hand tributary to the Barskoon river. Its bottom rises in the form of near-top steps over the gorge of this river (Fig. 2). The southern side of the szyrt is dominated by landscape typical of middle mountains with gently convex nival slopes, which is morphologically similar to the low mountains of Chukotka or Spitsbergen. The surroundings of the szyrt are devoid of Alpine-type landscapes, whereas its bottom is home to numerous glacial lakes, and surfaces of exaration reworking with the microrelief of roches montannées and greywethers.

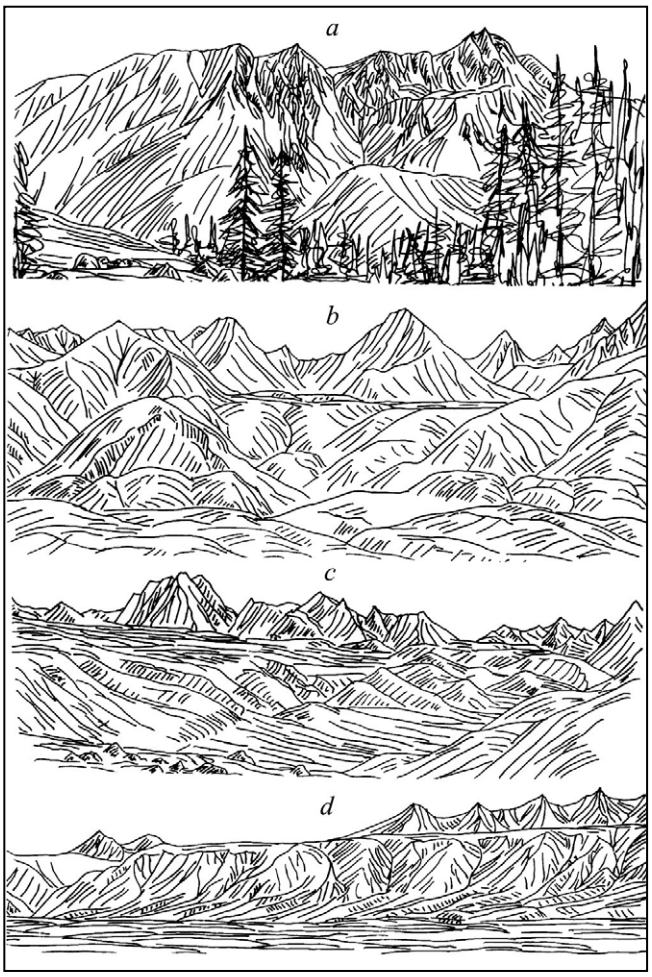

Fig. 1. Glacial steps at different development stages.

a – glacial cirque with destroyed walls on the left bank of the Dzheta-Oguz in Terskei-Alatoo; b – merged-together bottoms of glacial cirques; c – near-top step on the northern slope of Kungei-Alatoo; d – planate surface under the alpine-type relief at the southern side of the Susamyrskaya hollow.

Undoubtedly at the glacial epoch, the szyrt and its immediate mountain surroundings represented a rather extensive area of ice accumulation, while under the mantle of the glacier the relief was generated, which was different from an Alpine-type glacier inherent in areas of mountain-valley glaciation where the slope morphosculpture is formed mainly by gravitational fall deposits (e.g. screes) and snow

Fig. 2. Extensive screes and impact semi-craters on them produced by snow avalanches. The left side of the valley of the Barskoon river in Treskei-Alatoo.

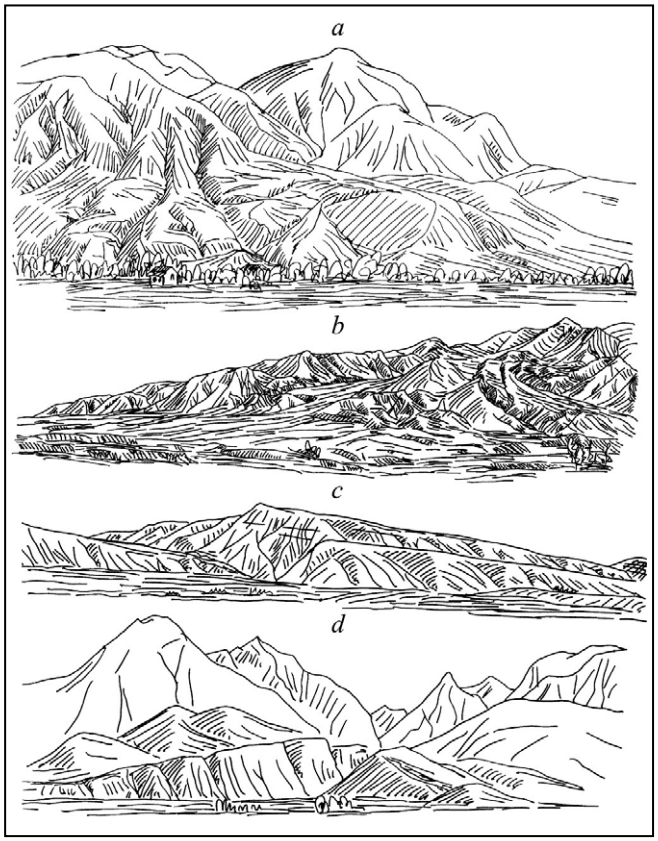

Fig. 3. Near-valley and submontane gentle-oblique surfaces in adyry of the northern slope of the Kyrgyz mountain range (a, b) and of the northern slope of Terskei-Alatoo (c, d).

avalanches. This is particularly true for the areas occupied by glaciers of Turkestan type [9] which are usually fed by avalanches. It is therefore not accidental that Alpine-type landscape occurs nearby (along the valley of the Barskoon river), and at considerably lower altitudes when compared with the bottom of the Arabelo szyrt. The steep sides of the valley here are scattered by numerous screes and rockfalls, while the near-top parts are home to the numerous narrow avalanche chutes. Snow avalanches impact the top parts and slopes of the screes thus generating in them semi-craters of different size (Fig. 3) which can be termed, according to their morphology and the way in which they are generated, the "avalanche anti-barkhans". Their location and occurrence on the slopes determine the boundaries of the areas experiencing the most hazardous action of snow avalanches.

The surfaces of glacial planation in the relief of the Western Tien Shan, i.e. the bottoms of szyrts and glacial steps in the near-top parts of the slopes of the mountain ranges, are polygenetic features, or surfaces of glacial plucking, and moraines. The bottoms of the szyrts are, to a certain extent, the surfaces of basal planation, although they are located at high altitudes and in the intermontane depressions. They have their origins in places of ice accumulation or beneath extensive ice massifs; possibly they are "real" equiplains. Glacial steps constitute suprabasal local peneplanation plains, or "small" equiplains of a sort.

Thus, regional and local peneplanation plains of several kinds are usually to be found in the Western Tien Shan mountains: pre-orogenic peneplanation plain (peneplain), exposed weathering fronts (etchplains), glacial planation steps, and equiplains. It would be appropriate to include here the surfaces of pre-orogenic peneplain which were reworked under the glaciers of flat tops. This list may be augmented if we turn our attention to examining the characteristic features of the relief of the piedmont adyry-ridges.

Characteristic features of the piedmont relief

Adyry are middle- and low-mountain, hill-mountain ridges or even terrace-shaped steps that accompany mountain ranges and usually have a cuesta-like shape with steep slopes facing the mountain ranges. They are composed largely by Cainozoic deposits and are the result of inversion uplifts of the marginal parts of depressions elongated into upwarpings coupled with the ranges. Adyry often combine to form ridges. Thus, on the southern shore of Issyk-Kul at the foothills of Terskei-Alatoo there can occur as many as three such systems of ridges. Adyry are one of the structural formations of the so-called arched-block (or Gobi) mechanism of recent orogenesis, and the mountains grow here through depressions by involving their marginal parts into the upwarpings [10]. In cases where the piedmonts of the arched ridges are made up by several adyry-ridges, it can be seen that the degree of skews of their broad (facing the depres-

sions) ramps is gradually increasing toward the mountain ranges, as is the height of the adyry-forebergs themselves. This is indicative of the stagewise character of expansion of the upwarpings where the amplitudes of the uplifts and skews progressively combine toward the inner adyry-ridges and, hence, we can define them as peculiar "tectonic quanta" of mountain growth.

Within the adyry chains there occur peculiar local gently sloping surfaces which are morphologically similar to the valley or piedmont pediments. Quite often they form two stages in the bottoms of the valleys or at the foothills of the adyry. This is distinctly exemplified by the area at the foothills of the northern slope of the Kyrgyz range, near the cities of Kant and Bishkek (see Fig. 3). On the northern slope of the Shekul on the left bank of the Alamedin river there are two steps of narrow gently sloping plains; one of them includes also the debris fans in the embouches of short valleys. The higher surface has a steep slope approaching a critical grade for pediments; it is coupled with the slope of the mountain massif via an angular convex knick.

Somewhat to the east, at the settlement of Syn-Tash, there are also two levels of gently sloping surfaces; they are both located not only within the base of the adyr slope but also are drawn into its confines along the valleys. Being outwardly suggestive of pediments, these surfaces have significant gradients which are not typical of pediments and make them akin to pedestals. And in either case, thy slope directions match those of the adyry-ridges.

The sides of large valleys intersecting the piedmonts of Terskei-Alatoo, such as Barskoon and Dzhety-Oguz, show near-valley oblique surfaces of a somewhat different appearance which were stripped in Cainozoic deposits. Thee are represented by narrow (a few hundred meters) oblique areas, coupled with the sides of the valleys via angular convex bends (and these limitations of them are rectilinear in plan), which is normally not inherent in the valley pediments. Their surfaces are inclined not only toward the bottoms of the valleys (see Fig. 3) but also descend downward, exhibiting a common skew, which is likely suggestive of their tectonic deformations in the process of intermittent inversion-controlled uplifts of the chains of adyry-forebergs. Here we observe something like the shears of river terraces arising due to differentiated tectonic movements [11]. On the left bank of the (western) Akterek valley, in the Kyzyl-Tuu adyr, it is clearly seen that its top surface and the level of the near-valley surface are gradually lowering coming closer together down the valley and toward Issyk-Kul (see Fig. 3), providing pictorial geomorphological evidence of the combination of the "quanta of tectonic skews".

The narrow near-valley surfaces in the adyry have a complex origin. Some of them are ordinary river terraces, while the others can be incised terraces, the inclined treads of which were formed during the lateral displacement of river flows with their gradual erosional deepening. And, finally, the piedmont surfaces that are drawn into the adyry along small valleys have a denudational origin.

The Tien Shan adyry usually imply the predominance of arid morphosculpture: fractional dissection of the slopes by short scours, and the occurrence of badlands with their whole picturesqueness of morphological landscapes. This is complemented by the many-colored pattern of Meso-Cainozoic deposits composing them devoid of vegetation mantle. On the walls composed by lithificated deposits there occur, in addition to slope erosion, microforms of temperature controlled exfoliation (desquamation), while on friable features there occur clayey or loamy sinters (mineral tears). These adyr landscapes are of significant recreational importance and are particularly picturesque in the northern piedmonts of Terskei-Alatoo where they neighbor upon the coast of Issyk-Kul. The picturesque, reworked (in the red rocks of the Kyrgyz formation) Dzhety-Oguz (Seven Bulls) rocks are widely known; equally attractive are the slope badlands of Urochishche Soguty or of the piedmont ridges at the settlement of Kadzhisai and of the valley of the Chu river at its entry into the Boomskoye gorge.

A large number of geomorphological natural monuments of the Tien Shan have one salient feature, namely, the are the consequence of the manifestation of hazardous geological processes on terrestrial surface. A particularly illustrative example in this regard is furnished by the traces of dislocation and gravitational movements of the rocks in epicentral zones of strong Tien Shan earthquakes, such as the Kebinsk earthquake that occurred in 1911 [12]. They provide striking examples of the fact that in most cases of strong seismic events, the main threat to humans are not the dislocations along the faults (linear or point disturbances of terrestrial surface) but the attendant rockfalls, screes or debris slides. Moreover, earthquake-induced tectonic deformations are not always manifest or emerge to terrestrial surface. Fractional erosional dissection, combined with a considerable steepness of the slopes, are responsible for the widespread occurrence of gravitational dislocations of friable masses which are often tectonically disintegrated across the terrestrial surface. Therefore, in forecasting earthquakes, analysis a the geomorphological situation in areas of their manifestation must constitute a mandatory element of seismogeological constructs.

This work was done with financial support from the Russian Foundation for Basic Research (05–05–64173).

References

1. Modern Geodynamics of the Tien Shan Lithosphere. Edited by N. P. Laverov. Moscow: Nauka, 1991, 192 p.
2. Chediya O. K. Morphostructures and Neotectogenesis of the Tien Shan. Frunze: Ilim, 1986, 314 p.
3. Shults S. S. Analysis of Recent Tectonics and Relief of the Tien Shan. Zap. Vser. geogr. ob-va. Novaya seriya (Transactions of the All-Russian Geographical Society. New series). Moscow, 1948, v. 3, 222 p.
4. Ufimtsev G. F. Tectonic Analysis of the Relief (Exemplified by the Eastern USSR). Novosibirsk: Nauka, 1984, 183 p.

5. Ufimtsev G. F. Mountain Belts of the Continents, and the Symmetry of the Earth's Relief. Novosibirsk: Nauka, 1991, 169 p.
6. Ufimtsev G. F. Morphotectonics of Eurasia. Irkutsk: Izd-vo Irkutsk. un-ta, 2002, 494 p.
7. Davis W. M. Geomorphological Studies. Moscow: Izd-vo Inostr. lit-ry, 1962, 544 p.
8. Demek J. Theory of Systems and Study of Landscape. Moscow: Progress, 1977, 223 p.
9. Leontiev O. K. and Rychagov G. I. General Geomorphology. Moscow: Vyssh. shk., 1979, 287 p.
10. Florensov N. A. Toward the problem of the orogenesis mechanism in Inner Asia. Geotektonika, 1965, No. 4, pp. 3-14.
11. Nikolayev N. I. Neotectonics and Its Expression in the Structure and Relief of the Territory of the USSR (Questions of Regional and Theoretical Neotectonics). Moscow: Gosgeoltekhizdat, 1962, 392 p.
12. Bogdanovich K. I. and Kark I. M. The earthquakes in the northern chains of the Tien Shan on 22 December 1910 (4 January 1911). Trudy Geol. komiteta. Novaya seriya. SPb, 1914, issue 89, 252 p.