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# Landscape distribution characteristics of northern foothill belts of Tianshan Mountains

作者: CHENG Wei-ming ZHOU Cheng-hu

The foothill belts of Tianshan Mountains are about 280 km long and 60 km wide, and the study area extends from Kuitun city to Fukang city. They are transitional belts between mountains and plains, appearing in three rows of folds with different morphologies and their age becoming younger from south to north. Based on GIS and RS methods, and materials of the previous researchers, this paper deals with the genetics of the foothill belts and their landscape features resulting from folding by neotectonic movements, and also describes their length, width and slope by remote sensing image interpretation. The characteristics of the foothill belts are found to be very important for the surrounding environment by preventing groundwater from flowing into plains, changing groundwater, increasing flow of surface runoff, in addition to their roles in protecting the surrounding environment. The purpose of this paper is to provide an in-depth understanding of the foothill belts and influence on its surrounding environment.?

Landscape distribution characteristics of northern foothill belts of Tianshan Mountains CHENG Wei-ming, ZHOU Cheng-hu, TANG Qi-cheng, YAO Yong-hui, ZHANG Bai-ping (State Key Laboratory of Resources and Environment Information System, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) 1 Introduction Since the 20th century, scientists have systematically researched formation and evolution, landforms, climate, glaciers, rivers and lakes, soil, distribution features of vegetation and animals of the Tianshan and Kunlun mountains and discussed in detail the geomorphic framework of the main mountains and landscape elements (CETX, CAS, 1978a, b; XIG, CAS, 1986). Li Baoxing researched and pictured 5 types of contiguous relationship between foothill belts and main mountains (Li, 1982), Tang Qicheng deduced that foothill belts could prevent groundwater from flowing into plains, increase outlet flow of mountains and enhance annual regulation capability of river runoff (CETX, CAS, 1966, 1978c; Li et al., 1958; Tang et al., 1992). Up to now, no definite definition has been given to foothill belts. Customarily, foothill belts are considered as low mountain region of the main ones. In addition to the difference of distribution place and vertical elevation, the cause of formation of foothill belts and main mountains also differs from each other. For example, modern Tianshan Mountains came from different upheavals of fault blocks by neotectonic movements, but foothill belts came from folding movements. So, foothill belts are regional system composed of low hills and interhills, located in front of the main mountains, having different formation cause and low elevation relatively from main mountains. As one of the unique geomorphic landscapes, foothill belts are extensively distributed in front of the Kunlun, Qilian and central Asian mountains as well as the Tianshan Mountains (CETX, CAS, 1978a, b; XIG, CAS, 1986). Examples of solving geoscience problems using RS are numerous, and prolific achievements have been gained (Chen et al., 1990; Zhou et al., 1999). Based on materials of the predecessors, detailed investigations to every landscape spectrums of the northern slope of Tianshan Mountains in August and September, 2000, measured data of geology, geomorphology, soil, and vegetation of foothill belts, TM images of the 1990s, topographic and geologic maps, landuse data, DEM etc., using GIS and RS, this paper systematically discusses formation, distribution scope and characteristics of northern foothill belts of Tianshan Mountains and their impacts on the surrounding environment. These achievements can provide a theoretical basis for researching horizontal and vertical landscape spectral change of mountains and plains, and interactions between highlands and lowlands, mountains and plains. 2 Formation of northern foothill belts of Tianshan Mountains The evolution of Tianshan Mountains underwent a long historical period of geology and complicated tectonic evolution of geology. Ocean trough of Tianshan Mountains experienced Caledonian and Hercynian orogeny, folded and upheaved t o shape Paleo-Tianshan Mountains in late Permian Period of late Paleozoic Era. After that it underwent denudation and deplanation and was leveled to the peneplain in late Mesozoic Era and early Tertiary Period. During the late Tertiary Period and the early Quaternary Period, most parts of the Tianshan Mountains experienced the Neotectonic Movements, different block upheaving movements along fracture belts and folding movement locating in foothill belts are the major manifestations (XIG, CAS, 1986). The northern foothill belts of Tianshan Mountains, which are about 280 km long and 60 km wide, extend from Kuytun to Fukang, appearing in three rows of folds and two rows of interhill basins (Figure 1), with their elevations ranging from 1,700 m to 800 m and their age becoming younger from south to north (XIG, CAS, 1986). 3 Landscape distribution characteristic of northern foothill belts of Tianshan Mountains 3.1 Landscape scale of foothill belts Distribution and scope of foothill belts are enumerated from south to north as shown in Figures 1 and 2. In Figure 1, 1 stands for south Manas fold; 2 stands for Qingshui River nose-shaped fold; 3 stands for Qigu fold; 4 stands for south Anjihai fold; 5 stands for Huorguos fold; 6 stands for Manas fold; 7 stands for Tugulu fold; 8 stands for Fukang fold; 9 stands for Dushanzi fold; 10 stands for Anjihai fold. 3.1.1 The first row fold belt: The fold belt abuts against Tianshan Mountains, it consists of south Manas anticline, Qingshui River nose-shaped fold structure and Qigu fold structure from west to east (Figure 1). 1) South Manas anticline lies in the upstreams of Manas River, with a length of 24 km, width of 6 km, an area of about 122 km2, average elevation of about 1,200 m, and an east-west long axial direction. 2) Qingshui River nose-shaped fold lies on the convergence place of Manas and Ningjiahe rivers, with a length of 20 km, width 6 km, area about 100 km2, average elevation about 1,300 m, and an east-west long axial direction. 3) Qigu fold lies in the upstreams of Hutubi, Santun and Toutun rivers, with a length of 84 km, width 8 km, area about 640 km2, elevation ranging from 2000 m to 1500 m, and a northeast-southwest long axial direction. This particular row fold belt consists of Jurassic layer, the red stratum of Tertiary Era only appears in north flank. The north flank slope is steep, and south flank is flat. 3.1.2 The second row fold belt: Expanding from east to west, this belt consists of south Anjihai, Huorguos, Manas, Tugulu and Fukang anticlines in a west to east order (Figure 1). 1) South Anjihai anticline lies 16 km south of Dushanzi, abutting against Tianshan Mountains, with a length of 24 km, width 8 km, area about 168 km2, average elevation about 1,000 m, an east-west long axis and a relative gentle north flank. 2) Huorguos anticline lies 18 km south of Anjihai, with a length of 52 km, width 18 km, area 512 km2, and an average elevation about 1,000 m. Long axis direction appears northwest-southeast, axis consists of lower Tertiary layer, south flank is made up of early Tertiary and late Pleistocene layers, and angle of slope is 20o-50o. 3) Manas anticline lies against Shihezi nearby, with a length of 28 km, width 12 km, area 244 km2, average elevation about 900 m, long axial direction appears east-west, slightly leaning north, and both slopes are gentle. 4) Tugulu anticline lies in front of Tianshan Mountains between Hutubi and Manas, with a length of 50 km, width 14 km, area 480 km2, and an average elevation about 1,000 m. The long axial direction appears northwest-southeast, angle of slope of north flank is more than 50o, but south flank is about 30o (XIG, CAS, 1986). 5) Fukang anticline lies in front of Tianshan Mountains between Urumqi and Fukang, with a length of 38 km, width 10 km, area 340 km2, an average elevation about 900 m, and east-west long axial direction. Figure 1 Distribution of structural landforms of northern foothill belts of Tianshan Mountains Figure 2 Distribution of folded structure of foothill belts and interhill basins in Manas River Valley, Tianshan Mountains (ETM image, July 4, 1999) 3.1.3 The third row fold belt: The belt lies against Shawan-Kuytun-Wusu nearby, with an anticlinal axial evaluation of about 800 m, consisting of Dushanzi and Anjihai anticlines from west to east (Figure 1). 1) Dushanzi fold lies against Shihezi nearby, with a length of 15 km, width 4 km, area about 48 km2, an average elevation about 1,000 m. Anticlinal axis is an interbedding of brown, gray sandstones with mudstone, south slope angle is 27o-35o, but north slope is 50o-80o (XIG, CAS, 1986). 2) Long axis of Anjihai anticline appears east-west, with its length of 50 km, width 5-6 km, area 260 km2, both flanks symmetric on the whole with angles being 20o-25o each. Taking 14 km apart from Anjihai Bridge to the west as boundary, the anticline can be divided into left and right ones. The length of the right one is 30 km, width is 30 km, area is 152 km2, and an average elevation is 750 m or so. The length of left fold is 20 km, width is 6 km, area is 108 km2, and an average elevation is about 850 m. The scale of the third row foothill fold belt is smaller than that of the second one, axial layer is Miocene, south flank is Pliocene and late Pleistocene series (XIG, CAS, 1986). 3.2 Landscape distribution characteristics of foothill belts The entire northern foothill belts of Tianshan Mountains are located in desert or desert steppe zone, foothill folds and interhill basins spread along east-west direction, but there are regional differentiations. Only the first and second rows of foothill belts are distributed between Fukang and Shawan; but the second and third rows are distributed between Shawan and Wusu (Figures 1 and 2). Among the northern foothill belts of Tianshan Mountains, the scale of second row foothill fold is the largest. The fold length of south Anjihai, Huorguos, Manas, Tugulu and Fukang totals about 185 km, average width is about 15 km while the fold length of both the first and third ro w of the foothill belts is only 60 km with an average width of 6 km. The slope map of foothill belts derived from 1:250000 DEM shows that slopes of alluvial fans and desert (white) are less than 5o; slopes of interhill basins are about 5o (white); and slopes of two flanks of the folds are about 5o-30o (green) (Figure 3). Figure 3 Slope distribution map of the foothill belts derived from 1:250000 DEM 3.3 Soil and vegetation distribution characteristics of foothill belts Grey scale and veins of foothill folds are completely different from those of alluvial fans and interhill basins (Figure 2). In TM image, red blocks of alluvial fans are oases that are channeled and irrigated with river water. The second and third rows of folds and flanks appear greyish-green, numerous gulches dotted with red speckles of vegetation are discernible. Field investigation shows that most of these areas are bare rocks, only few having Quaternary soil overlaid. With dry climate, vegetation is very sparse and coverage measured is less than 5% (Yuan et al., 1995), while in folds and flanks of the first row of foothill belts vegetation coverage is about 20%. The interhill basins are covered by Quaternary deposits on the whole. Mountain glasslands in red are located in high elevations leaning against the first row fold and spread bandingly along rivers or gulches. With coverage being about 25-35%, these basins serve as perfect autumn and winter pastures (Yuan et al., 1995). Desert steppe situated in low elevation leaning against the second row fold becomes greyish-green or banded white with coverage being about 10%. Both sides along rivers have been transformed into oases. In places in front of Tianshan Mountains without foothill belts (such as west of Kuytun), alluvial fans are directly contiguous with main mountains. In the dry climate environment, vegetation is very sparse, with a coverage of less than 5%. Local people can only utilize earthy areas of the clinoplain to exploit oases, and other areas are desert or Gobi that can not be exploited at present (Yuan et al., 1995). 4 Impact of foothill belts on surrounding environment As one of the unique geomorphic landscapes, foothill belts have important impacts on the surrounding environment. Firstly they can prevent groundwater from flowing into plains. Impermeable foothill folds separate groundwater in interhill basins from alluvial plains, and bulky suspended loads carried by rivers accumulate in basins. Groundwater replenishment to rivers takes place in the form of outcroppings of springs in low-lying lands, increasing flow of the surface runoff, so interhill basins become groundwater reservoirs, which can adjust river flow (CETX, CAS, 1966, 1978c; Li et al., 1958; Tang et al., 1992). Calculation results of hydrologic data of Hongshanzui station in Manas River (major river, with foothill belts), Hapodi station in Toutun River (small river, with foothill belts) and Jilede station in Sikeshu River (small river, without foothill belts) covering 1955 to 1989 show percentage of groundwater to river flow is over 45% at mountain gaps, but that of groundwater without foothill belts is 10% less than that with foothill belts at mountain gaps, indicating the certain regulating effect of foothill belts on stream runoff. Secondly, foothill belts have impacts on oasis. Distribution and expansion of oasis has a close relationship with distributing scope and morphological structure of foothill belts. With foothill belts and thick sediments, alluvial fans and plains are ideal places to be exploited into oases, such as Manas, Hutubi and Fukang etc. But without foothill belts (for example, west of Kuytun), both interannual and intra-annual changes of rivers are great, so the regulating capacity of rivers is weak, which affects development of oases. Moreover a wide range of desert and Gobi in the foreland of the mountains is very difficult to be exploited and utilized, so the smaller area and scale restraint sustainable development of oasis. Figure 4 Relationship between buffer incidence from foothill belts and distribution of precipitation Thirdly, foothill belts have impacts on climate and vegetation. Foothill belts are safeguard barriers of mountains; they can delay dry-hot air current coming from desert area into mountains, and can prevent cold airflow of mountains from entering into plains. In winter, thermal inversion layer appearing at forest belts can play a protective role by avoiding cold current invasion due to protection impact from foothill belts. Overlaying buffer effect range derived from foothill belts and contours of precipitation (Figure 4) can show clearly influence of foothill belts on local climate. With foothill belts, contours of precipitation stretch into plains, precipitation amount in the mountains is very ample, moreover there exist two centers with maximum precipitation in mid mountains, where forest belts are just located. In Manas River Valley, precipitation amount of forest belts is 500-600 mm, annual average temperature is 0-3 oC, the hottest monthly average temperature is 9-15 oC, and the coldest monthly temperature -10 ? -15 oC. In contrast to plain areas, because of protection of foothill belts, in forest belts, it is cooler in summer and warmer in winter. Under wet climate conditions, annual temperature changes are insignificant. Precipitation amount of foothill belts is 200-300 mm, annual average temperature 3-6 oC, the hottest monthly average temperature 21-24 oC, and the coldest monthly temperature -15 ? -17 oC. Precipitation amount of alluvial fan is 140 mm or so, annual average temperature 6-7 oC, the hottest monthly average temperature 24-26 oC, and the coldest monthly temperature -17 ? -19 oC (Yuan et al., 1995). In area west of Kuytun without foothill belts, more annual temperature changes and more abnormal climate occur compared with other places. Precipitation amount at Jinghe is only 91.1 mm, lower limits of forest belts are above 400 m than that of Manas River Valley (Yuan et al., 1995). Comparing with

8 typical vertical belts of the Tianshan Mountains, every landscape belt with foothill belts is 100-200 m lower than other regions without foothill belts. These all show important protective influence of foothill belts on surrounding environment. 5 Conclusions and discussion According to the achievements of predecessors and field investigations, using GIS and RS, this paper discusses in detail landscape distribution characteristics of northern foothill belts of Tianshan Mountains, and analyzes their impacts on surrounding environments (for example, river flow, oasis development, local climate, vegetation, soil etc.). These can provide a theoretical basis for researching interactions of highland and lowland, mountains and plains. As one of the unique geomorphical landscapes, how mechanism and dynamic simulation of foothill belts adjust river flow and affect surrounding environments will get detailed answer by means of up-to-date technology and field investigations in the future. References

关键词： foothill belts; foothill landscape; geomorphic landscape; geomorphic remote sensing; Tianshan Mountains

 