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AN APPROACH TO THEORY AND METHODS OF URBAN GEOMORPHOLOGY*

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ABSTRACT: Urban geomorphology is a new subject, and its theory and practice need approaching and substantiating. This paper deals with the utilization and transformation of landforms in the process urbanization, and the evolvement and unique character of an urban geomorphological environment. Taking an evaluation about catastroability of the urban geomorphological environment in Chongqing as an example, the author introduces a researching method in the urban geomorphology, including selection and quantification of evaluation parameters, a grid method used in mapping and a mathematical synthesizing method to evaluate on a fixed position.
KEY WORDS: urban geomorphology, urban geomorphological environment, Chongqing City

Supported by National Natural Science Foundation of China, we have made an experimental research in Chongqing, Sichuan Province, since 1987 in order to approach the theory and methods on the urban geomorphology in China. This paper gives a brief theoretical summarization of our researches on the urban geomorphology, and taking an evaluation about catastroability of the urban geomorphological environment as an example, explores the ways and means of researches on the urban geomorphology.

I. URBAN GEOMORPHOLOGICAL ENVIRONMENT

Since the Second World War, the urbanization in the world has been developing so quickly that some scholars call it "urban revolution".

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An important manifestation of urbanization is the expansion of a city. In China, the area of urban districts was 195,000 km^2 in 1978 and 870,000 km^2 in 1986. In other words, the areal proportion of urban districts in the whole territory has gone up from 2% to 9.1% for 8 years[1].

In the urbanization process, the ways and means of land-use have been changed, then urban landforms have been changed clearly and profoundly. Compared with other ways of land-use, such as agriculture, animal husbandry and forestry, the way of land-use in cities shows some unique characteristics.

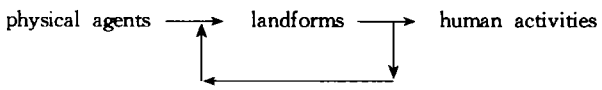
Landform is a basic part of urban environment. Geomorphic substance with various shapes and materials is a underlying surface for a city and an important factor to control the layout, regional structure and development of a city. Meanwhile, a lot of artificial activities in a city are so frequent that physical geomorphological substance is destroyed and transformed, physical geomorphological process is disturbed and altered, and new artificial geomogphological substances are reformed. A city is an area where artificial activities are always more initiative and concentrative, and the contradictory and unity relationship between man and landforms is greatly notable[2]. Therefore, there are some unique characteristics in an urban geomorphological environment.

1. Artificial Geomorphological Agent

According to traditional geomorphology, landforms are produced by endogenic and exogenic agents. So, an evolution of landforms is an objective process independent of man's will. The relationship among physical agents, landforms and human activities is simply linear:

physical agents→landforms→human activities

In urban areas, the evolution of landforms relates to not only physical agents, but also human activities in the engineering and economic fields. An urban geomorphological environment is a common result of physical agents and human activities. Then, there is a non-linear relationship and a feedback mechanism between landforms and human activities in cities:



2. Structure of Urban Geomorphological Environment

Urban geomorphological environment can be divided into 3 parts: physical

landforms, artificial landforms and physi-artificial landforms.

Physical landforms are the landforms which are not or hardly effected by human activities. They lay a macroscopic framework for the distribution of the other parts of landforms, which produces an impact on the expansion, structure and pattern of cities, and are constantly replaced by the other parts of landforms with the development and expansion of cities.

Artificial landforms are various man-made architectures, such as buildings, bridges and roads. They are made up after physical landforms were destroyed by human activities. In general, artificial landforms are made of various building materials, in obvious shapes, and become an important part in an urban geomorphological environment. They make a great impact on hydrologic and geomorphic characteristics of the land and on properties and structure of the soil in cities during and after the building period. An urban geomorphological environment would hardly recover its natural state even if artificial landforms would be destroyed or disappeared.

Physi-artificial landforms mean those physical landforms reformed in varying degrees by human beings, such as a channel fettered by man-made banks, artificial lawns and green belts. Physi-artificial landforms have some characteristics of both physical and artificial landforms. In general, they are results of a common action of exogenic and artificial agents, in a background of the action of endogenic agents.

3. Regional Differences in Urban Geomorphological Environment

In varying parts of a city, there are differences in effecting intensity and acting way of the artificial geomorphological agent. Therefore, there are notable regional differences in urban geomorphological environment.

3.1 *Urban fringe*

An urban fringe is an expanding area of a city where various building activities are initiative, concentrative and frequent. Here, landforms are destroyed and changed very quickly, erosion and sedimentation on the ground are accelerated by frequent building activities and usage of a lot of building machines and vehicles, stability of slopes is lowered by the artificial cutoff, unload at slope foots and add-load on slope tops. These artificial activities change shapes and materials of slopes and provide a high sensitive area for development of gullies. In the river system, a channel's shapes and flowing ways are changed, then the equilibrium in rivers is destroyed. These effects can bring about some sudden mass movements and other processes, such as landslides, breakdown, debris flow and floods, and do damage to cities.

In brief, the geomorphological environment in the urban fringe is highly sensitive to urbanization due to a lot of intense activities of the artificial geomorphological agent. It can be called "geomorphological environment"

3.2 *Built-up area of a city*

The built-up area is a centre of economic activities of a city, where various artificial landforms, including skyscrapers, parks and squares, are so concentrated that they become major landscapes in the urban environment. In this area, the geomorphological environment can be called "an urbanized geomorphological environment".

The concentrated artificial landforms give a powerful impact on thermodynamic and aerodynamic processes in the geomorphological environment because they were made up of various building materials, whose thermal conductivity, specific heat and specific reflection are not the same as those of natural materials. Because of these man-made effects, the speed and direction of geomorphic processes have been changed greatly.

In the built-up area of a city, various man-made grounds, such as building's roofs and pavements, cover over 90% of the ground. Researches show that a runoff coefficient of the un-permeable ground is more than 75%, but that of the natural ground is only 30%. That means precipitation causes a small amount of runoff on a natural ground, but a quite great amount of runoff on a un-permeable ground, especially during rainstorm. There are drainage systems in the built-up area of a city. The runoff flows at a higher speed through the drainage systems and converges into a river more quickly, which causes a more discharge and a higher water level in a river in a flood peak[3-4].

In sum, urban geomorphological environment with unique characters has formed along with the utilization and transformation of landforms in urbanization process, followed by changing characters in the urban geomorphological researches. Therefore, urban geomorphological researchers ought to analyse relations and reactions between the urbanization and the geomorphological environment from contradictory movements between geomorphological environment and man's activities.

II. A METHOD USED IN URBAN GEOMORPHOLOGICAL RESEARCH

In urban geomorphological researches, it is necessary to choose essential elements of landforms and to use a suitable analysis method on the basis of geomorphological reality and urban needs[5-8]. Here, talking an evaluation about catastroability of urban geomorphological environment as an example, we introduce a method used in researches on Chongqing urban geomorphology.

1. Landforms and Disasters in Chongqing City

In many cities, the geomorphological environment, including forms and processes of landforms, is correlated directly to the mechanism and processes causing disasters and affects the distribution of disasters. We call this correlation "a catastroability of an urban geomorphological environment"[9].

Chongqing, with a population of near 3.5 million is one of the extra-large cities in China, it is situated at the confluence of the Changjiang (Yangtze) River and the Jialing River in the southeast part of Sichuan Basin. The city proper is in a wide synclinal valley sandwiched between two ranks of lower mountain running from north to south. Major types of landforms are lower mountains with an elevation of 500—800 m, hills and platforms with an elevation of 200—400 m. There are large various slopes where red Mesozoic stratum, mainly sandstone, mudstone and shale with a weaker anti-erosional ability, are exposed. Under the subtropic monsoon and humid climate with the annual average temperature of 18.4℃ and the annual precipitation of over 1,000 mm, various mass movements and fluvial processes, the two major geomorphological processes in Chongqing City, are so active that some disasters, such as landslides and breakdowns, can be brought on.

Researches show that the urban geomorphological environment is directly correlated to the distribution and frequency of urban disasters. For example, urban disasters are distributed in belts along landforms, and landslides are mainly on monoclinal slopes and bank-slopes of rivers. According to statistics, 69.18% of disasters happened on the slopes with gradient over 30°, 28.31% on the slopes of 15°—30° and 2.51% on the slopes under 15° in the city. It is evident that the stability of slopes is lowered easily by physical factors such as rainstorm and mass movements, and human activities such as building and cut off, which causes various geomorphological processes on slopes, resulting in disasters in the urban area[10].

2. Quantitative Evaluation on Fixed Position

2.1 *Selection of evaluation parameters*

Four geomorphological elements were chosen as evaluating parameters in evaluating catastroability of the urban geomorphological environment in Chongqing City. They are slope gradient, relief degree of ground, gully density and elevation. The former two are thought to be a reflection of downward forces and potential energy of a mass of materials on slopes, or the latent pow-

er causing breakdowns and landslides, they can be a numerical judgement of the catastroability of gravitative processes on slopes. The latter two are expressions of ranges and extents of fluid operating in rivers and gullies, or extent and region where floods and debris flows could be destructive, they can be a numerical judgement of catastroability of fluid processes[11].

2.2 *A grid method*

A grid method is used in mapping to provide a basis of a fixed position for researches. According to urban landforms and needs of the city, 0.04 km^2(200 m×200 m) is fixed for a mapping unit, or a check, and the researched region is divided into 3,732 mapping units in Chongqing City. Working maps are at the scale of 1:10,000 and compiled maps are at the scale of 1:50,000.

2.3 *Quantitative evaluation*

Evaluating work is made in each check on the working map. The data of four evaluating parameters are exchanged into evaluating indexes (Table 1). Then, a composite index, i.e. the general disaster index (*GDI*), can be obtained after these evaluating indexes are synthesized mathematically by their weight. *GDI* reflects, on numerical value, the catastroability of the geomorphological environment in an evaluating unit. The formula to evaluate the composite index (*GDI*) is:

$$GDI_i = \sum_{j=1}^{n} W_j X_{ij}$$

where, GDI_i: composite index in i evaluating unit;

n: number of evaluating parameters;

W_j: weighted enumerator of j parameter;

X_{ij}: evaluating index of j parameter in i unit

Table 1 Evaluating index of parameters

Evaluating index (X_j)	1	2	3	4	5	6
Elevation (m)	>195	193−195	190−193	187−190	184−187	180−184
Slope gradient (%)	<5	5−15	15−30	30−50	50−70	≥70
Gully density (km. km^{-2})	<1.25	1.25−5	5−10	10−15	≥15	−
Relief degree (m)	<20	20−35	35−60	60−80	80−100	>100

* The evaluating index of elevation is determined by the water stage of floods with different reappearance periods. In their given order, the reappearance periods of floods are 100 years, 50 years, 20 years, 10 years, 5 years and 1 year.

3. Statistics and Analyses

On the basis of numerical value of *GDI*, the catastroability of the urban geomorphological environment, Chongqing City is divided into 4 grades: grade I means light danger, grade II means middle danger, grade III means more danger and grade IV means serious danger. Then, "The Map of Catastroability Grades of Urban Geomorphological Environment in Chongqing City" has been compiled.

The statistics in Table 2 and the map show two characters of catastroability of the urban geomorphological environment in Chongqing City: the latent dangers causing disasters are serious and evaluating units with distinct grades are distributed mixedly. The former indicates that there are more serious disasters in the urban geomorphological environment in mountains and hills than those in plains. The latter means it difficult to use urban landforms in mountains and hills, such as Chongqing City. Therefore, it is complicated and difficult to take precautions against urban disasters and reduce their damages in Chongqing City[12].

Table 2 Statistics of catastroability grades of the urban geomorphological environment in Chongqing

Grade	I	II	III	IV	Total
Numbers of units	609	1595	1260	268	3732
Area (km^2)	24.36	63.80	50.40	10.72	149.28
Areal percentage (%)	16.3	42.7	33.8	7.2	100

Up till now, most of lands with grade I and a part of lands with grade II have been used as the urban built-up area in Chongqing. It can be predicted that the city would expanse to the lands with and grade II and III. Then, it is predictable that urban disasters would be caused more frequently and make greater damages to the city unless the urban geomorphological environment would be given more rational uses and under a better protection.

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