Research on the Tolerance Erosion Value of Soil on Weathering Granite Parent Material*

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Abstract: In this paper, the granite weathering soil in The Three Gorges Dam region of Yangtze River is chosen as study region. Using the principle of landform process, through reconstruction paletopograpgy, and inferring initial denudation ages and layer, the denudation rate of granite are calculated. Taking Taipingxi small watershed as comparing research region of geological period and present, the recent erosion intensity is deduced from sediment data. Further, the standard of soil loss tolerance, being widespread used present, in weathering granite soil region is referenced. The results is as follows: ① Denudation rate in geological period is 16mm/ka — 38mm/ka, the greatest denudation ratio is about 47 mm/ka; ② Present, In Taiping stream small drainage, average soil erosion rate is 297.7mm/ka, minimum value is 31.5mm/ka; ③ Recently, weathering granite soil loss tolerance value is decided as 76.9mm/ka by Chinese Ministry of Water Resources. Conclusions show that the later is 2 — 4 times of former. So the new point on determination soil loss tolerance are firstly presented, that when soil loss tolerance is determined, parent rock weathering denudation intensity must be taken into account.
Keywords: weathering granite soil, weathering intensity, parent rock, soil loss tolerance

1 introduction

To determinate soil loss tolerance is a very complex and must be researched problem. It plays a very important part in overall arrangement of soil and water conservation measures, regulation of land utilization types and soil sustaining utilization. Recently, soil loss tolerance value is decided with the rate of soil formation, soil properties characteristics and crop growth requirement over world. The formation rate of soil parent material—weathering regolith is not taken into account. In thick loess region, the soil loss tolerance value being decided with this way is scientific and reasonable. However, in the soil region of weathering rock parent material, the weathering and denudation intensity of parent material must be taken into account, because the formation rate of soil parent material corresponds to the weathering rate of parent rock. If soil erosion rate is greater than weathering intensity of parent rock, the soil should lose formation parent material in a number of years. Present, there is widespread rockening and roughness of soil in southern China.

It is a very important geological problem, how to determinate weathering and denudation of parent rock. It implicates substance geological circulation and geomorphic evolution. The weathering and denudation intensity of parent rock in the geological period can be calculated in terms of remaining weathering regolith thickness and ancient landforms evolution characteristics. Compared denudation rate at present with geological period in local, speeding up erosion velocity by human can be calculated and the value of soil loss tolerance in local can be determinated.

For this purpose, It is necessary to select a typical study area, in where stratums must is completed and geological tectonic element must is integrated, there are various land utilization types and ground surface matter is relative correspondence-granite and weathering granite regolith. Axle center region of Huangling anticline conformed to the demands. It is located in eastern reaches of Three Gorges of

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Yangtze. The Xiling Gorge cut deeply into south part of Huangling. The dam of Three Gorges of Yangtze is situated in here. It will be very significant to control sediment in reservoir area after dam finished, to determinate soil loss tolerance by weathering and denudation ratio in geological period.

2 Weathering and denudation of granite in the cenozoic era*

At present, geanticline geomorphologic landscapes are result from suffering long-terms tectonic rising and weathering and denudation action. In order to calculate weathering and denudation ratio in geological period, it are necessary to reconstruction and recovering ancient environment. By compared present topographic rising and downfall to the geologic, the denudation ratio in geologic period could be calculated. Again according to the relationship principle of denudation and deposition, time span suffering denudation could be inferred on the base of deposit sediment near deposited region. Future, weathering and denudation ratio could be calculated in geologic period. The processes of paleotopographic construction in Huangling anticline region are as follows.

First，on the topographic maps of 1:500,000，on the base of contour lines characteristics，6 section lines were selected and vertical topographic profile maps were drawn. Thus，present topographic rising and falling characteristics of Huangling anticline presented itself before our eyes.

Second，on the geological and stratums maps of 1:200,000，according to rock stratum thickness, rock stratum dip angle and dip direction, and contact relationship of different geological period, various geological elements were filled in vertical topographic profile maps.

Third，on the base of rock stratum dip angle and dip direction filled in vertical topographic profile maps, the same rock stratum contact directly with granite both sides of anticline were oppositely extended into joining. Joint were regarded as paleotopographic mountains peak. The vertical height difference between paleotopographic mountains peak line and present mountains peak line were taken as denudation thickness.

Fourth， taking topographic turning points, drainage system and different height topographic surfaces as calculation unit, weathering and denudation thickness were separately measured and calculated. On this base, average weathering and denudation thickness was calculated, by principles of densely choosing points and weighted average.

In vertical topographic profile maps of 6, 85 points (X_i) were equidistantly selected on abscissas. 100 m were regarded as a height unit on ordinates. The probability (P_i) of each height unit presented among 85 points were:

$$P_i = \frac{n_i}{85}$$

Average denudation thickness (E) was calculated by mean of mathematics expectation:

The calculated result showed that average denudation thickness was 959m in granite distribution region of Huangling anticline.

$$E = \sum_{i=1}^{85} P_i X_i$$

Last, in terms of isotope ages (60Ma) of sedimentary rock bottom of Jiamacao formation in Jianghan plain， in where granite gravel from Huangling anticline were initially deposited, and denudation thickness of various topographic places, the denudation ratio of different topographic places and various drainage systems and average were calculated (Table 1,Table 2, Table 3). The greatest denudation ratio is about 47 mm/ka. It occurred in valleys and gullies. The average denudation ratio was 15.98 mm/ka in granite distribution region of Huangling anticline.

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Table 1 The denudation thickness and intensity at each topographic turning point in granite region of HuangLing anticline

Profile order	Present mountain peak place denudation		Paleotopographic mountain peak place denudation		Maximum denudation	
	Thickness (m)	ratio (mm/ka)	Thickness (m)	ratio (mm/ka)	Thickness (m)	ratio (mm/ka)
Ⅰ	380	6.33	420	7.00	900(Letian stream)	15.00
Ⅱ	700	11.67	1,300	21.67	1,300(Baishui stream)	21.67
Ⅲ	620	10.33	1,700	28.33	1,940(Letian stream)	32.33
Ⅳ	1,300	21.67	2,200	36.67	2,800(Letian stream)	46.67
Ⅴ	900	15.00	1,380	23.00	1,620(Baishui stream)	27.00
Ⅵ	580	9.67	580	9.67	990	16.50

Table 2 The denudation thickness and intensity on various topographic level in granite region of HuangLing anticline

Profile order	Different height denudation ratio											
	height (m)	Thickness (m)	Ratio (mm/ka)	height (m)	Thickness (m)	Ratio (mm/ka)	height (m)	Thickness (m)	ratio (mm/ka)	height (m)	Thickness (m)	ratio (mm/ka)
Ⅰ	1,900	380	6.33	1,700	420	7.00	1 220	540	9.00			
Ⅱ	1,600	700	11.67	1,060	1,000	16.67						
Ⅲ	1,270	620	10.33	910	1,700	28.33	540	1,140	19.00			
Ⅳ	1,900	1,300	21.67	1,300	1,900	31.67	1,000	1,900	31.67			
Ⅴ	940	900	15.00	780	800	13.33	580	700	11.67	420	900	15.00
Ⅵ	1,600	700	11.67	1,300	1,000	16.67	800	700	11.67	460	550	9.17

Table 3 The denudation thickness and intensity in valley system in granite region of HuangLing anticline

Profile order	Baishuixi denudation		Taipngxi denudation		Letianxi denudation		Zhetianxi denudation		Yangtze valley denudation	
	Thickness (m)	Ratio (mm/ka)	Thickness (m)	Ratio (mm/ka)	Thickness (m)	Ratio (mm/ka)	Thickness (m)	Ratio (mm/ka)	Thickness (m)	Ratio (mm/ka)
Ⅰ	700	11.67			1,000	16.67	700	11.67		
Ⅱ	1,300	21.67			900	15.00	500	8.33		
Ⅲ			1,360	22.60	1,940	32.33	940	15.67	1,260	21.00
Ⅳ									1,800	30.00
Ⅴ	1,620	27.00	820	13.67	1,180	19.67	560	9.33		
Ⅵ									700	11.67

3 Present soil erosion in weathering granite soil region

3.1 Typical small drainage—Taiping stream small drainage

There are 5 greater stream systems, which are Baishui stream, Letian stream, Zhetian stream, Maopng stream and Taiping stream drainage in Huangling anticline granite distribution region of Three

Gorges reaches of Yangtze River. In these stream systems, only Letian stream and Taiping stream drainage are all convered with granite and weathering granite regolith on the ground surface. During preparing construction of Three Gorges Dam of Yangtze River from 1980, Sediment and hydrology state were began to survey in Taiping stream drainage. At same time, committee office of soil and water conservation of upper reaches of Yangtze River approved the foundation project of “An analysis on benefit of decreasing sediment by store runoff and practicing soil and water conservation in Taiping stream drainage”. In project research, sediment and hydrology states were systermly observed and observation data accumulated [1]. As a result, this paper taken Taiping stream drainage as a typical small drainage to study its soil erosion intensity.

3.2 General situation of Taiping stream drainage

Taiping stream small drainage is located on north bank of Yangtze River of southern part of Huangling anticline and 5 km apart from the dam site of Three Gorges. It covers 26.136 km^2 and inclines from north to south. Its main stream course is length of 9.75km and stream bed gradient is 9%. Landforms dominated by mountains and hills with the maximum elevation of 1,321m and minimum elevation of 50m. In the whole drainage, average slope grade is with a gradient of 24.7° and average length of slope is 977m. Because of steep topographical and stream bed gradient, swift torrential flow have great erosion energy. Zonal soil is yellow brown earth and yellow soil, but severe soil erosion coarsened soil surface material. Zonal vegetation types are subtropical zone evergreen broad-leaved forest, coniferous forest and needle-broad-leaved mixed forest. Because most of them are brought under cultivation, natural vegetation covered only 37%. In whole drainage, land utilization states are described in Table 4. Slope cultivated land and barren mountain wasted slope land are main land utilization types suffering severe erosion. Land area suffering erosion accounted to 50% of total drainage area. Average annual erosion amount is about 8.31×10^4t.

Table 4 Land utilization component in Taiping stream drainage

Land utilization types	Area (hm^2)	Taking percentage of total drainage area (%)
Cultivated land	349.1	15.08
Forest land	969.6	37.1
Barren hill and wasteland	830.67	31.78
Barren rock	195.2	7.47
Water area	79.8	3.05
Others utilization land	144.27	5.52

Table 5 The intensity and area of soil erosion in Taiping stream drainage

Soil erosion grade	Area（km^2）	Accounting to percentage of total erosion area％
Very severe	2.2	15.9
Severe	5.1	37.0
Moderate	6.19	45.3
Slight	0.27	1.8

These figures are calculated from reference 1.

3.3 Soil erosion state of Taiping stream drainage before controlling soil and water loss

During 1950s—1980s, many researchers studied the soil erosion modulus distribution rule of Yangtze River valley. The soil erosion intensity of Huangling anticline granite distribution region were incorporated into moderate soil erosion region, its erosion modulus respectively was 1,000t/(km^2 • a)—5,000t/(km^2 • a) [2], 1,000t/(km^2 • a)[3], and 2,559t/(km^2 • a)[4].

On the base of surveying data of 1983 from the station of soil and water conservation of Yichang county, sediment transport modulus was 1,600t/(km^2 • a) in Taiping stream drainage (only calculated suspension transport sediment). However, according to surveying data from runoff plot, the ratio between suspend load and bed load was from 1:0.43 to 1:2.1 [5], in view of the above calculated, the amount of soil loss might amount to 2,288t/(km^2 • a) — 5,000t/(km^2 • a).In the total erosion area, the area of moderate and above grades accounted for 98% of the total area. The area of various erosion intensity grades were described in Table 5.The erosion values in various types of land utilization were respectively cultivated slope land being 3.57×10^{4}t, Barren hill and wasteland being 5.2×10^{4}t, forestland being 1.5×10^{4}t. cultivated slope land with a gradient of 25°—30°,maximum being 50°were main soil erosion formation in rainstorm season.

3.4 soil erosion development tendency in Taiping stream drainage

The rainfall and runoff data gained by observation for 1983—1992 were sorted and calculated. In order to compared with weathering regolith remaining ratio in geological period, sediment transport modulus are converted into denudation thickness (Table 6) in terms of average unit weight of local granite（2.6g/cm^3）[6、7].

Table 6 Hydrological factors of 1983—1992 in Taiping stream small watershed

years	precipitation (mm)	Runoff (10^4m^3)	Runoff coefficient	Amount of sediment transport(10^4t)	Modulus of sediment transport (t/(km^2 • a))	Denudation intensity (mm/ka)
1983	1,823.7	3,706	0.78	4.19	1,600	615.4
1984	1,528.0	3,100	0.78	4.94	1,890	726.9
1985	1,302.0	1,829	0.54	1.55	593	228.5
1986	1,148.8	1,583	0.58	0.75	286	110.0
1987	1,322.5	2,459	0.71	0.62	236	90.8
1988	1,448.5	2,578	0.68	5.20	1,990	765.4
1989	1,541.3	1,978	0.49	0.99	378	145.4
1990	1,053.9	1,502	0.55	0.22	81.9	31.5
1991	1,094.9	1,675	0.59	1.29	493	189.6
1992	1,231.0	1,339	0.42	0.51	193	74.2
Average	1,349.4	2,175	0.61	2.02	774.1	297.7

With the increasing of control degree of soil loss , the soil erosion modulus trended to decreasing. Compared hydrological factor data in 1989 to 1984, two of them were very similar in precipitation, but the runoff coefficient and sediment transport modulus evidently decreased. The decreasing degree of sediment transport modulus was the greatest. Rainfall is main factor caused soil erosion, but rainfall intensity and long terms are key processes to cause soil erosion. Rainfall data of 29 sets in 10 years showed that precipitation of 68.1% main concentrated in 6—9 mouth and the greatest rainfall intensity is up to 145.3mm/24h in Taiping stream drainage. it might express that ground surface denudation occurs mainly in the rainfall terms of great intensity and amass rainfall amount.

It is the major measures of decreasing soil loss to rationally readjust land utilization types (Table 7). In the processes of controlling soil and water loss for decades, sediment transport amount has been decreased by a big margin as the area decreasing of slope cultivated land and barren hill and wasteland and the area increasing of forestland and grassland. Its main mechanism of protecting ground surface is that vegetation of forests and grasses decrease striking power of rainfall and increase the roughness degree of ground surface[8].

Table 7 The change tendency of sediment and slope cultivated area and the covered rate of forest and grass in Taipingxi small watershed

Years	Slope cultivated area		Barren hill and Wasteland(hm^2)	forestland grass covered area percentage(%)	Sediment (10^4 t)
	Total(hm^2)	>25° (hm^2)			
1983	213.6	89.4	637.5	44.6	4.19
1984	181.7	31.9	404.6	54.1	4.94
1985	158.9	28.3	356.1	56.3	1.55
1986	132.3	20.0	342.5	57.4	0.75
1987	97.7	15.9	233.2	62.1	0.62
1988	73.4		172.8	64.8	5.20
1989	44.9		158.5	65.8	0.99
1990	28.5		61.1	69.9	0.22
1991	16.9		41.5	70.4	1.29
1992	0.2		18.9	72.0	0.51

4 Analysis and discussion

Since there are weathering regolith with various thickness on the ground surface, it can explain that denudation intensity is less than weathering ratio of parent rock. Otherwise, there are not weathering regolith on the ground surface. According to calculated of denudation ratio ground surface, average weathering ratio over world were calculated, which are respectively as follows: these were 0.5mm/ka in level ground, 5mm/ka—10mm/ka in slope land, 25mm/ka—50mm/ka in granite distribution region of tropical zone, 15mm/ka—30mm/ka in subtropical zone region, 14.3mm/ka—10mm/ka in arid and semiarid region. The denudation ratio should less than weathering ratio in the same region. Average denudation ratio were calculated by researcher from Japan, according to sediment load modulus of rivers over world. These separately were 13mm/ka in permafrost zone of northern of Canada and Russia and Sweden, 30mm/ka in temperate continental forest zone, 38mm/ka in temperate humid forest zone, 154mm/ka in the temperate grassland and desert zone, 16mm/ka in the tropical grassland and desert zone, 224mm/ka in the tropical forest zone. In terms of drainage statistical data of 14 in Taiwang, average denudation ratio is 389mm/ka； On the base of drainage statistical data of 21 in Japan, average denudation ratio is 329mm/ka[9] .Average denudation ratio of Yangtze river valley is 133 mm/ka [10]. In this paper, in Taiping stream drainage drainage, average denudation ratio is 297.7mm/ka, the greatest denudation ratio is 765mm/ka. It is far greater than others temperate humid forest zone over world with 38mm/ka, and is similar only in 1990 year. Compared to that calculated in geologic period, the greatest denudation ratio is 47.8times, and the lest denudation ratio is 1.97times. If parent rock were denudation at this speed in geologic period, there would not be how thick weathering regolith.

Currently, average soil denudation is greater than in the geologic period over world. It can express that：(1) Because man steep slope land cultivated, cutting forest, reclaim wasteland and overgraze, soil erosion and sediment load trend to increase. It shows clearly that man accelerate erosion is very serious; (2) If soil goes on being denuded at present ratio for future long-terms, the thickness of weathering regolith would trend to decrease. It results in the roughness and rockened of cultivated slope land; (3) In order to let soil regularly develop, soil denudation ratio would less than and equal to weathering regolith formation ratio. Otherwise, soil would degeneration. So this denudation ratio should be determined as soil loss toleration.

In the southern granite region, the value of soil loss toleration was determined as 200t/(km^2 • a). by Water Resources Ministry in China, on the base of regional characteristics [11], and convert denudation intensity as 76.9mm/ka in Taiping stream drainage. However, average weathering and denudation ratio of parent rock is 16mm/ka—38mm/ka. The difference of both is about 2 times. If soil were denuded at this speed, soil would rapidly lose formation parent material-weathering regolith. There will be not significance to talk about soil. In view of the above result, parent rock weathering ratio must be main factors being considered when soil loss toleration is determinated.

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