SOIL DEVELOPMENT PROPERTIES AND THEIR EVOLUTION WITH TIME IN THE PIEDMONT OF THE YUMUSHAN MOUNTAINS OF THE HEXI CORRIDOR

XING Chengqi
(*Lanzhou Institute of Seismology*, *CSB*, *Lanzhou* 730000)
LIANG Xiaopeng
(*Lanzhou University*, *Lanzhou* 730000)
ZHANG Jie DONG Zhiping
(*Lanzhou Institute of Seismology*, *CSB*, *Lanzhou* 730000)

Abstract

This is a methodological research on the chronology of soil development with the view of dating active structures in the piedmont of the Yumushan mountains of the Hexi corridor, China. Based on chemical analyses of soil samples systematically collected from test pits dug on terraces of different periods and ^{14}C and thermoluminescence dating of these terraces, the authors made a detailed study on the primary physical and chemical features of soil development in this region related to the new fault activities, as well as their evolution law with time. The quantitative relations of the content and accumulation index value of $CaCO_3$ in soils to ages of soil development were established preliminarily. Examination and contrastive analysis show that the established formulae are applicable to the active fault dating in similar areas.

Key words **Hexi corridor**, **Active fault**, Soil development, Dating method, Yumushan mountains

1 Introduction

The results of pedological research reveal that many features of the soil are closely related with the length of its development time. This relation comprises not merely the physical features of soil, such as color, structure, massiness and thickness, but also many chemical properties, such as the contents of calcium carbonate, secondary plaster and secondary ferric oxides and certain chemical elements. Therefore, the ages of soil and its Quaternary sediment and fault can be calculated based on the principle of the temporal evolution of some or overall characteristics of soil in its development and by using the quantitative equations between soil property and development age or the soil property accumulation rates established by statistical approach. This dating method by using soil development has been widely applied in the measurement of the age of active structures and Quaternary strata[1~7] and is exhibiting irreplaceable advantages and broad prospects of development and application[8~10].

The pedochronological method is set up on the basis of the detailed analysis of and research on soil profiles, which bear the features of layered development. In arid and semi-arid areas, soil of normal development is of three layers: eluvial horizon (A), illuvial horizon (B), and parent material horizon (C), which are basic unit horizons of a soil, and for highly developed soil its every horizon may be further divided into several sub-horizons. Material shifts and variations occur all the time in all horizons. The extent of soil development and the evolution law with time are most clearly shown in horizon B. For example, in the piedmont of the Yumushan mountains of the Hexi corridor, the soil contains rich calcium, most obvious in horizon B, and the maximal content value of $CaCO_3$ in the soil profiles are all in the same horizons, mostly in which calcic accumulation horizons have formed and their features and $CaCO_3$ contents all change regularly with the development ages of the profiles. Such regularities are the foundation on which soil age is able to be determined.

It should be pointed out that soil development is influenced by various factors. It is the function of climate, parent material, vegetation, landform and time. The hypothetical condition for soil dating is for all elements except time to maintain their constants, taking into account only the temporal relation of evolution, in order to obtain the information of age and temporal variations for the calculation of soil development in other sites. As landform conditions can be controlled in operation and vegetation is conditioned by climate, soil dating method is generally practicable in the areas with identical or similar climatic and parent material conditions.

2 The Developmental Features of the Soil in the Piedmont of the Yumushan Mountains

The Yumushan mountains are crosswise upheaval in the middle of the NWW Hexi corridor (Fig. 1) on the north and east edges of which grow two active faults: the former is of thrust and overthrust nature, while the latter is of right-lateral slip with compression. Both have experienced strong activities since the late Pleistocene and relics of 2 to 4 palaeoearthquakes have remained[11, 12]. The violent uplift of the Yumushan mountains in the Quaternary resulted in thick alluvium-proluvium, forming the piedmont Gobi plain. Along the foot of the mountainsare multi-period proluvial fans and multi-level alluvial-proluvial terraces on which are natural soils developed to dif-

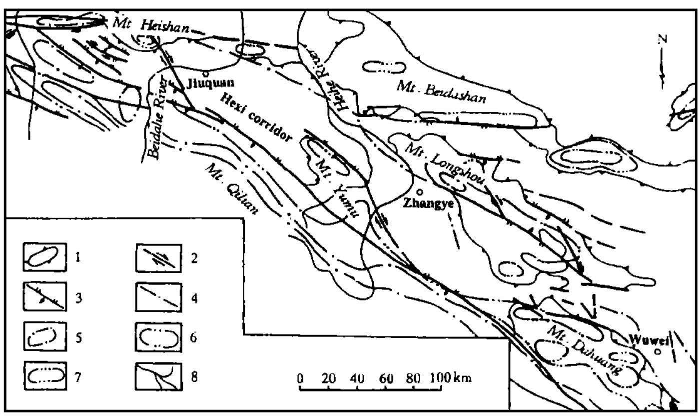

Fig. 1 Neotectonic map of the Hexi corridor.
1 Pre-Quaternary bed outcrop area; 2 Quaternary strike-slip fault;
3 Quaternary thrust and reverse fault; 4 Geophysical prospecting or inferred fault;
5 First-order planation surface; 6 Second-order planation surface;
7 Third-order planation surface; 8 River
Altitude above sea-level of the first-order planation surface:
from 3 600 m to 5 000 m for west segment of Mt. Qilian;
from 3 200 m to 4 000 m for east segment of Mt. Qilian;
from 2 800 m to 3 200 m for Mt. Beishan and 2 000 m for Mt. Heishan.
Altitude above sea-level of the second-order planation surface:
from 3 200 m to 3 600 m for west segment of Mt. Qilian;
from 2 800 m to 3 200 m for east segment of Mt. Qilian;
3 000 m for Mt. Dahuang; from 1 800 m to 2 000 m for Mt. Beishan.
Altitude above sea-level of the third-order planation surface:
from 2 600 m to 2 800 m for Mt. Qilian; 1 500 m for Mt. Beishan.

ferent degrees. We have made detailed field investigations of the soils and undertaken systematic analysis of and research on the well-developed terraces in the mouth of Heihe river at the eastern foot of the Yumushan mountains. Specifically speaking, the work includes: 1) systematically determining and calculating the formation ages of the terraces by thermoluminescence and ^{14}C dating methods and estimating the height of all terraces along the Heihe river; 2) detailed description of and systematically sampling from the 6 prospecting trench profiles on the first-to fifth-levels of terraces and the small first-level earthquake terrace between the third-and fourth-levels of terraces with a gross chemical analysis of 36 soil samples; and 3) contrasting the soils from terraces of defferent periods and studying change of their physicochemical characteristics with time.

2.1 The Development and Formation Ages of Terraces in the Mouth of Heihe River

In the valley, 5 levels of fluvial terraces (T_1, T_2, T_3, T_4 and T_5 in Table 1) are well developed (Fig. 2). In addition, two other small earthquake terraces (T_e^1 and T_e^2) are discovered between the third- and fourth-level terraces in the upside of the fault on the northeastern bank of the river[12]. Among 5 levels of fluvial terraces, formation ages of four were determined by numerical dating technique. These four terraces are T_2, T_3, T_4 and T_5, of which the former two are ^{14}C age and the latter two thermoluminescence age (Table 1). By adopting the ages and heights of these terraces, four undercutting rates of the Heihe river may be obtained since the formation of corresponding terraces, an average rate of 1.81 mm/a since the late Epipleistocene (approx. 40 000 a B. P.) at the foot of the mountains and by adopting the formation age of the second-level terrace (12 250 a ±350 a by ^{14}C) and its height a mean undercutting rate of

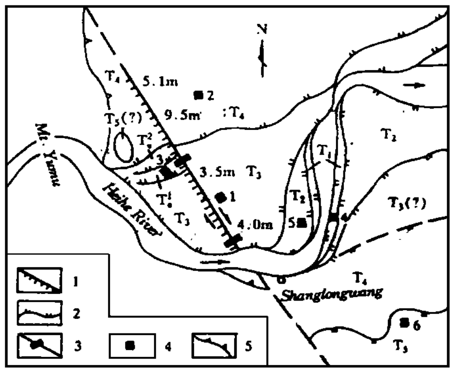

Fig. 2　Distribution of faults and terraces at the mouth of Heihe river.

1 fault scarp and its throw (the side with short lines is upside of fault); 2 terrace and its number; 3 palaeoearthquake trench; 4 soil trench and its number; 5 boundary of basin

Table 1　Data of the terraces at the mouth of the Heihe river *

Terrace			T_1	T_2	T_3	T_e^1	T_e^2	T_4	T_5
Terrace Height (m)			3~5	12	33	36	39	44	94
Formation age/ka	TL		—	—	—	—	—	26±1	38±3
	^{14}C		—	12.3±0.4	15.7±0.2	—	—	—	—
	SL		5	—	—	19	21	—	—
Undercutting rate /[mm·a^{-1}]	Single rate		—	0.976	2.102	—	—	1.692	2.474
	Average rate	Since Q_4	0.98		—	—	—	—	—
		Since late Q_3	1.81						

* Terrace height refers to the height between terrace surface and river bed; TL is the thermoluminescence age; SL is the age of terraces based on the average undercutting rate of the river. ^{14}C dating was done by Zhang Yutian and Cao Jixiu of Lanzhou University; Thermoluminescence dating was done by Liu Aiguo and Hu Bifang and checked by Lu Yanchou of the Institute of Geological Research, China Seismological Bureau.

0.98 mm/a will be calculated for the river since the Holocene epoch. Based on the above two values, ages of formation will be achieved for the other two small terraces and the first-level terrace (Table 1).

It is necessary to explain that the above-mentioned four numerical age samples were collected from the top of sand-gravel layer of corresponding terraces and the bottom of the thin overlying loess or soil. Therefore, their ages should represent the years of completion of their own terraces or the years of the fluvial deposit termination and undercutting initiation. They may also be the beginning ages of soil development on the terraces. It should be pointed out that the formation age obtained on the basis of the fluvial undercutting speed for the two small seismogenic terraces (Fig. 2) might be a little older according to judging by their formation as a result of undercutting the upside after the abrupt faulting, therefore, the undercutting rate is obviously bigger than the normal. For this reason, the ages of the previous two small seismic terraces should represent the maximum value.

2.2 The Physical Characteristics of Soil Development

The soil of the researched region develops under the condition of arid desert and semidesert. The soil-forming parent material is composed of alluvial-proluvial gravel, grit and thin loess layer. The profiles bear aridic epipedon, secondary clayization and gypsification. The soil is of strong calcareous nature with $CaCO_3$ relatively concentrated, mostly having formed calcareous accumulation horizon. Therefore, the soil in this area is fundamentally calcic-orthic aridisol type[13]. The calcic accumulation horizons of only a small number of young profiles are less developed whose content values of $CaCO_3$ exceeding those in the parent material horizons are slightly less than 5%.

Field investigations revealed an obvious division of soil horizons whose degree of development increased with increasing age of profiles. The most evident was the horizon B (illuviation horizon), which was characterized chiefly by the thickening and subdividing of the layer, the darkening of its color, the reinforcing of its compactness, the augmenting of calcareous reflection, the strengthening of viscosity and the extending of gypsification.

2.3 The Chemical Characteristics of Soil Development

By X fluorescence spectrum analysis of the contents of the 36 soil samples from 6 profiles on different terraces at Heihe river mouth, 8 oxides and 16 elements were identified (Table 2). The $CaCO_3$ content analysis was also executed with the results in Table 2.

The analysis of $CaCO_3$ showed that the soil in this area is obviously of calcic accumulation, there is rich $CaCO_3$ in horizon B with a depth between 7 and 70 centimeters. The most striking case was sub-horizon B_1 whose depth is between 8 and 40 centimeters and in which there is generally the maximal $CaCO_3$ content value of over all profile. In addition, with the increase of age of the profiles, the content of $CaCO_3$ in the profiles apparently increased on the whole (Fig. 3), and the calcic accumulation horizon thickened and its subhorizons multiplied.

The analysis of oxides showed that the extent of mineral composition shifting in the profiles was not even. Compared with the parent material, the movement of Ca, Na and K was relatively marked, that of Fe, Al, Mg and Ti was slight and that of Si relatively stable. Among all these components, Ca shifting was the most obvious, its high content occurred in horizon B and its content increases with increasing age of the profiles (Fig. 3). The horizon B also contained a high value of Na which slightly increases with time (Fig. 4). Ti, on the other hand, was mostly distributed in horizon A and there was no evident regularity of change with the development age of the profiles. The maximum content of Fe was mostly in horizon A, but some in horizon B. Fe and Al demonstrated the same tendency of slight decrease in content with the increasing time (Fig. 5). Such change which disagrees with usual circumstances deserves further research.

Table 2　Chemical data from the soil profiles at the mouth of Heihe river in the eastern piedmont belt of Yumushan mountains*

Profile No.	Profile location and age/ka	Sampling depth/cm	Soil horizon/subhorizon	Results of analysis(%)								
				$CaCO_3$	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2
HPit-4	T_1	0~8	A	10.98	57.63	12.27	5.42	6.04	3.25	2.52	1.42	0.66
	5	8~18	B	13.20	58.72	12.23	5.44	5.56	3.20	2.47	1.53	0.66
		18~36	C	8.87	61.69	10.74	4.99	5.38	2.92	2.18	1.71	0.65
HPit-5	T_2	0~13	A	13.53	57.21	11.08	4.92	6.87	3.52	2.37	1.81	0.64
	12.3	13~28	B_1	15.10	55.58	11.07	4.91	7.39	3.82	2.35	2.05	0.62
		28~46	B_2	13.72	57.33	11.10	4.93	6.63	3.71	2.37	2.09	0.60
		46~61	C_1	12.37	57.86	11.14	4.82	6.55	3.43	2.36	2.05	0.61
		61~94	C_2	6.53	63.13	11.64	4.91	3.91	2.90	2.49	1.94	0.60
HPit-1	T_3	0~8	A	15.05	56.72	10.95	4.88	7.26	3.64	2.35	2.01	0.64
	15.7	8~21	B_1	16.34	53.65	11.14	4.77	8.30	4.02	2.35	2.67	0.63
		21~35	B_2	14.02	58.14	10.49	4.69	6.89	3.45	2.27	2.39	0.64
		35~46	B_3	14.72	58.06	10.63	4.67	6.90	3.51	2.30	2.35	0.63
		46~60	C	13.90	58.59	10.50	4.65	6.65	3.40	2.27	2.82	0.63
		60~68	$2B_1$	13.50	58.10	10.83	4.74	6.71	3.39	2.34	2.24	0.60
		68~79	$2B_2$	14.25	56.26	10.77	4.70	7.52	3.64	2.33	2.33	0.60
		79~90	$2B_3$	14.15	56.43	11.00	4.74	7.41	3.37	2.38	2.18	0.59
		90~105	2C	9.62	63.10	9.59	4.68	5.39	2.74	2.09	2.00	0.59
HPit-3	T_e^1	0~16	A	14.04	57.01	10.93	4.85	7.05	3.48	2.35	1.89	0.65
	19	16~28	B_1	17.07	54.25	10.89	4.77	8.16	3.98	2.36	2.33	0.59
		28~38	B_2	14.07	58.89	10.43	4.66	6.65	3.43	2.26	2.27	0.61
		38~62	C_1	11.66	53.18	9.52	4.18	8.41	2.98	2.06	1.97	0.53
		62~90	C_2	14.26	57.83	10.51	4.63	7.22	3.17	2.30	2.11	0.60
HPit-2	T_4	0~14	A	15.83	54.74	10.96	4.83	7.99	3.61	2.36	1.80	0.65
	26	14~36	B_1	19.79	50.76	10.11	4.49	10.29	3.82	2.22	2.24	0.57
		36~54	B_2	14.13	47.27	9.50	4.21	10.45	3.43	2.03	2.04	0.53
		54~73	B_3	15.02	55.77	10.34	4.46	8.13	3.28	2.29	2.18	0.57
		73~93	C_1	13.67	56.23	10.25	4.38	7.79	3.05	2.24	2.02	0.57
		93~110	C_2	11.78	56.51	9.78	4.18	7.67	2.80	2.14	1.93	0.56
		110~125	C_3	9.22	64.42	9.98	4.53	5.75	2.67	2.16	2.07	0.57
HPit-6	T_5	0~14	A	14.11	58.11	10.67	4.74	6.67	3.40	2.26	2.32	0.65
	38	14~28	B_1	14.01	58.62	10.40	4.36	6.97	3.83	2.26	2.60	0.57
		28~39	B_2	17.18	56.39	9.69	4.40	8.21	3.22	2.06	2.70	0.55
		39~49	B_3	9.79	63.31	9.62	4.26	5.42	2.75	2.05	2.14	0.57
		49~75	C_1	9.03	64.26	8.72	4.00	5.52	2.34	1.90	1.86	0.53
		75~89	C_2	11.32	59.00	9.82	4.25	6.69	2.80	2.13	2.01	0.57
		89~110	C_3	15.40	56.44	10.98	4.64	6.98	2.17	2.44	2.62	0.52

* Analyzers: Sun Zhong and Jia Huilan of Lanzhou Desert Research Institute, Chinese Academy of Sciences

3 The Quantitative Evolution Relationship between Chemical Properties and Development Age of Soil

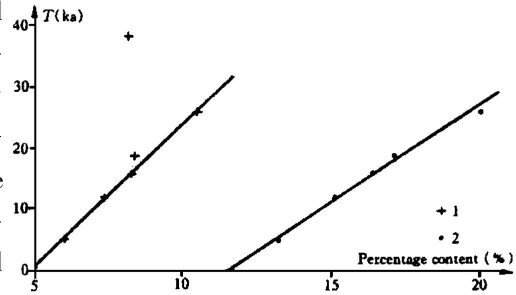

Fig. 3 Changes of the contents of CaO and $CaCO_3$ in the soils with time.
1 CaO (maximum content in each profile);
2 $CaCO_3$(maximum content in the horizon B)

As stated above, many soil features are related with the age of development, including quite a number of chemical components, e. g. $CaCO_3$, secondary gypsum, etc., usually increasing with the age of development. Statistical correlations exist between the age of development and the content of chemical components. Therefore, regression equations can be used to undertake a quantitative description of their relationship.

In the chemical components analyzed, the relations between contents of CaO and $CaCO_3$ and development age were the closest, and the contents of both clearly increase with time. Considering that there is correlation between the contents of CaO and $CaCO_3$ in soil in arid and semiarid regions, the content of $CaCO_3$ was of marked characteristic significance with regard to the degree of soil development. For this reason we chose only $CaCO_3$ for statistical analysis and regression equation establishment.

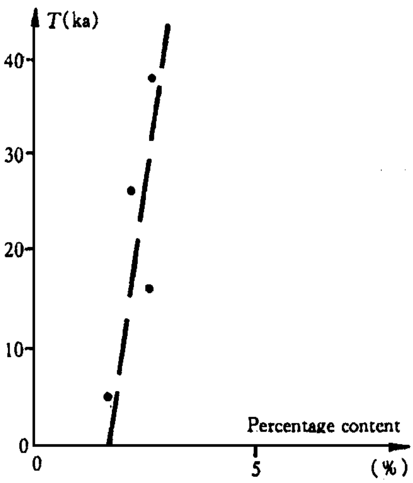

Fig. 4 Change of Na_2O content (maximum content in each profile) in the soils with time.

3.1 $CaCO_3$ Content-age Regression Equation

Scatter diagram was drawn according to the contents of $CaCO_3$ in Table 2 (the maximum value in horizon B of all profiles) and the years of formation for terraces on which the soil profiles were located. From Figure 3 it may be seen that the great majority of data are almost on a straight line, except one datum being abandoned for its great dispersion. Computation reveals that the content of $CaCO_3$ and the age of development conformed to linear regularities. A linear regression equation with one unknown quantity was obtained:

$$Y = -37.36 + 3.254X \quad (1)$$

where Y stands for age in 10^3 years and X for the percentage of $CaCO_3$. From formula $r = lxy \sqrt{lxxlyy}$ we obtained the sample correlation coefficient $r = 0.997$, from the check list we get $r_{0.05}(3) = 0.878$. It may be seen that the sample correlation coefficient is close to 1, evidently greater than the salience, and thus proves the obvious linear correlation between the content of $CaCO_3$ and the years of development.

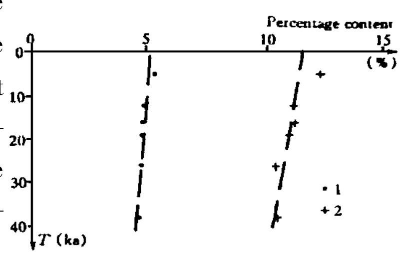

Fig. 5 Changes of the contents of Fe_2O_3 and Al_2O_3 in the soils with time.
1 Fe_2O_3(maximum content in each profile);
2 Al_2O_3(maximum content in the horizon B)

3.2 Regression Equation of $CaCO_3$ Accumulation Index Value and the Age of Development

From Table 2 and the previous sections, we know that the soil in the researched area had a rich content of $CaCO_3$ mainly in horizon B and mostly forming calcic accumulation horizon. In order to make an objective account of this soil feature, according to the train of thought for calculating the clay accumulation index value of soil profile of Levine, et al. (1982) we advanced that a $CaCO_3$ accumulation index value can be used to represent the degree of horizon B or calcic horizon development. Using X to stand for the index value, the method of calculation for each soil profile is as follows:

$$X = \sum [(B_a - C_\beta) \times H]$$

where B_a stands for $CaCO_3$ content (%) in horizon B, C_β is $CaCO_3$ content (%) in horizon C_1, and H is the thickness of the horizon B (cm). When the $CaCO_3$ content of the maximum $CaCO_3$ content subhorizon in B horizon exceeds that of its underneath subhorizon by more than 5%, C_β takes the average of $CaCO_3$ contents in subhorizon C_1 and in the bottom subhorizon of horizon B. The $CaCO_3$ accumulation index values of all soil profiles at the mouth of the Heihe river are listed in the Table 3.

Table 3　Data of ages and $CaCO_3$ accumulation index values of the soil profiles

Soil profiles	HPit-4	HPit-5	HPit-1	HPit-3	HPit-2	HPit-6
Location and terrace	T_1	T_2	T_3	T_e^1	T_4	T_5
ages of formation/ka	5	12.25±0.35	15.69±0.16	19	26±1	38±3
Accumulation index values	41.5	65.25	73.6	89.02	116.12	149.87

A diagram (Fig. 6) was drawn according to the data of $CaCO_3$ accumulation index values and terrace formation ages in Table 3, showing a very good linear relation between both and for all data almost to be on the same straight line. One linear ($Y = a + bX$) and two logarithmic ($Y = a + b \log X$) and $\log Y = a + b \log X$) models were chosen in calculation to contrast and determine the degree of fitness between different regression equations and actual data. Three calculated equations are:

Linear: $$Y = -7.19 + 0.298X \quad (2)$$

Logarithmic: $$Y = -91.689 + 58.01 \log X \quad (3)$$

$$\log Y = -1.748 + 1.545 \log X \quad (4)$$

whose correlation coefficients are respectively 0.998, 0.980 and 0.992, of them the correlation degree of equation (2) is the highest, that of equation (4) is higher and that of equation (3) is the lowest, but all higher than the levels of significance tests (See Table 4).

From what has been discussed above, it can be seen that the accumulation index value of $CaCO_3$ is better correlated with the age of soil development than its pure content value.

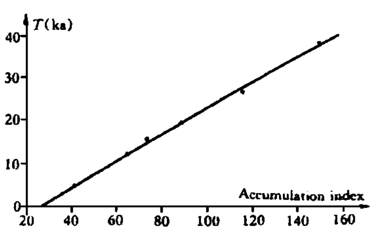

Fig. 6　The variation of the $CaCO_3$ accumulation index values in the soil profiles with time.

3.3　Verification Analysis

Four regression equations were obtained in the calculation of the content and the accumulation index value of $CaCO_3$ relating to the age of soil development, of which two are linear and the rest two are logarithmic. The equations as well as their correlation coefficients and verification are listed in Table 4.

Table 5 lists the results of verification for the four equations. The actual dating and the calculated ages as well as their errors are given in this table. From Table 4 and Table 5 it may be seen that among the four equations, (1) and (2) are in best agreement with the actual data, having high correlation coefficients and very small errors, which shows the marked relevance between the content (or the accumulation index) of $CaCO_3$ in soil and development age. In addition, equation (4) is still sensible in spite of a few big errors which are basically limited within the same order of magnitude with the error of actual dating. Therefore, the three equations above may be classified into preliminary quantitative formulae in actual dating work. Semi-logarithmic equation (3) proves to be a failure and therefore not to be applied.

Table 4 Regression equations relating the content and the accumulation index value of $CaCO_3$ in soil to soil age

No.	Chemical components	Model	Regression equation	Correlation coefficient r	Correlation coefficient verification (5%)
1	$CaCO_3$	Linear	$Y=-37.36+3.254X$	0.997	0.878
2	$CaCO_3$	Linear	$Y=-7.19+0.298X$	0.998	0.811
3	Accumulation	Semi-logarithmic	$Y=-91.689+58.01\log X$	0.980	0.811
4	index	Logarithmic	$\log Y=-1.748+1.545\log X$	0.992	0.811

Table 5 Contrasts between the ages calculated by the regression equations and the actual dating ages

Soil profile	HPit-4	HPit-5	HPit-1	HPit-3	HPit-2	HPit-6
Location	T_1	T_2	T_3	T_e^1	T_4	T_5
Ages determined by ^{14}C, TL and SL/ka	5.0	12.25±0.35	15.69±0.16	19.0	26.0±1	38.0±3
Ages calculated by formula 1	5.6	11.8	15.8	18.2	27.0	—
Error	+0.6	−0.5	+0.1	−0.8	+1.0	—
Ages calculated by formula 2	5.2	12.3	14.7	19.3	27.4	37.5
Error	+0.2	+0.1	−0.9	+0.3	+1.4	−0.5
Ages calculated by formula 3	2.2	13.6	16.6	21.4	28.1	34.5
Error	−2.8	+1.3	+0.9	+2.4	+2.1	−3.5
Ages calculated by formula 4	5.6	11.4	14.1	18.3	27.7	41.1
Error	+0.6	−0.9	−1.6	−0.7	+1.7	+3.1

4 Conclusions

From what we have studied above, it can be concluded that in the piedmont area of the Mt. Yumushan with arid and semi-arid climatic conditions, the content of $CaCO_3$ in soil and the years of soil development bear remarkable positive correlations, and the accumulation index value of Ca-CO_3 has higher correlation with the age of development than its pure content value, which may more objectively reflect the development degree of soil profiles. Of the four quantitative equations established above, three ((1), (2) and (4) in Table 4) are in good agreement with actual data, which are practicable for actual dating of active structures and late Quaternary geomorphologic surfaces in the same kind of regions. The application and further improvement of these equations may help determine the best formula thereof.

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REFERENCES

1 Machette M N. Dating Quaternary faults in southwestern United States using buried calcic paleosols. Jour Research U S Geol Survey, 1978, 6(3): 369~381.

2 Machette M N. Calcic soils of the southwestern United States. Geol Soc American Special Paper, 1985, 203: 1~21.

3 Colman S M, Pierce K L. Use of weathering rinds on andesitic and basaltic stones as a Quaternary age indicator, Western United States. U S G S Professional paper, 1981, 1210: 56~60.

4 Levine E R, Ciolkosz E J. Soil development in till of various ages in northeastern Pennsylvania. Quaternary Research, 1983, 19: 85~99.

5 Harden J W, Taylor E M. A quantitative comparison of soil development in four climatic regimes. Quaternary Research, 1983, 28: 342~359.

6 McFadden L D. Changes in the content and composition of pedogenic iron oxyhydroxides in a chronosequence of soils in southern California. Quaternary Research, 1985, 23: 189~294.

7 McFadden L D, Weldon R Y. Rates and processes of soil development on Quaternary terraces in Cajon Pass, California. Gelo Soc Amer Bull, 1987, 98: 280~293.

8 Keller E A. Investigation of active structures-the application of surface terrestrial process methods. See: Active Tectonics. Transl. by Sichuan Provincial Seismological Bureau. Chengdu: Sichuan Science and Technology Press (in Chinese), 1989. 156~173.

9 Pierce K L. Method of Dating in Active Tectonics. Transl. by Sichuan Provincial Seismological Bureau. Chengdu: Sichuan Science and Technology Press (in Chinese), 1989. 230~254.

10 Xing Chengqi. Soil dating method and its application. Northwestern Seismological Journal, 1997, 19(3): 76~80.

11 Li Yulong, Xing Chengqi. Research on the fundamental characteristics of the geological structures of the Hexi corridor and the active faults of the northern and eastern flanks of the Yumushan Mountains in China. Northwestern Seismological Journal, 1988, 10(2): 35~47.

12 Xing Chengqi. A preliminary research on the active Shanglongwang fault and its prehistoric big earthquakes. Northwestern Seismological Journal, 1987, 9(supp.): 113~117.

13 Hu Shuangxi, Wang Naian, Zhang Jiaen. Study on taxonomic classification of calci-orthic aridisols in Northwestern China. See: Recent treatises on Chinese soil taxonomic classification. edit. by Editorial Board of Research Series on Chinese Soil Taxonomic Classification. Beijing: Science Press, 1994. 40~48.

河西走廊榆木山前土壤发育特征及其随时间的演变关系*

邢成起
（中国地震局兰州地震研究所，兰州 730000）
梁晓鹏
（兰州大学，兰州 730000）
张 杰 董治平
（中国地震局兰州地震研究所，兰州 730000）

摘要

在河西走廊榆木山前开展了旨在用于活动构造测年工作的土壤发育年代学新方法的研究. 通过在不同时代河流阶地上开挖土壤探槽、系统采集土壤样品并进行化学成分分析，以及对各级河流阶地形成年代的^{14}C和热释光年龄测定，详细研究了该区与断层新活动有关的土壤发育的主要物理和化学特性及其随时间(年代)的演变规律，初步建立起了土壤$CaCO_3$含量和$CaCO_3$累积指数值与发育年代之间的定量计算关系式. 经回检和对比分析认为，所建立的定量计算关系式可适用于同类地区活动断层和晚第四纪堆积地貌面的实际测年工作.

主题词 **河西走廊 活动断层** 土壤发育 测年方法 榆木山

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第一作者简介：邢成起，男，1959 年生，副研究员，主要从事活动构造与年代学方法研究.