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A PRELIMINARY DISCUSSION ON EVOLUTION OF XI'AN GROUND FISSURE (1985—1989) AND ITS MECHANISM

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Abstract

The active pictures of XGF (Xi'an Ground Fissures) are given and analysed. Both tectonic characteristics and artificial characteristics of XGF are shown. The tectonic control functions on XGF appear not only geometrical but also mechanical, the former can be seen from space distribution feature and geometrical pattern of XGF, the latter can be seen from its formation process, as well as the time feature of earthquakes and XGF. The human activities, mainly overextraction of piezometric ground water, result in land subsidence in Xi'an. The ununiform land subsidence is responsible for high rate of the movement of XGF, which is about ten times higher than the rate of tectonic movement. According to the major rate (the rate of vertical slip), XGF is classified into three grades. The map of XGF classification well reflects its multiplicate cause mechanism.

Introduction

Ground fissures occurred in large area of China before and after the Tangshan disaster earthquake (1974—1979). The provinces where the ground fissures appeared actively are Jiangsu, Shandong, Anhui, Henan, Hebei, Shanxi, Shaanxi etc.. During this period, there were more than 2000 localities of ground fissures to cover over 0.6 millon sq. km. Just at the same time, XGF attracted people attention by its high rate of movement and the severe damage to Xi'an city (the total economical loss is more than 20 million Yuan). In fact, it becomes a special geological disaster. The cause of Xi'an ground fissures is very complicated. Scientists in Xi'an accept the challenge and manage to get the answer. Some papers and works have been published on the bases of present results of the research. We studied the development of XGF, analysed various causes and their functions in making of XGF. Considering XGF is a special fracture of earth, we researched the physical mechanism of its formation and development. It will be useful for further studying and seeking the countermeasures against the disaster.

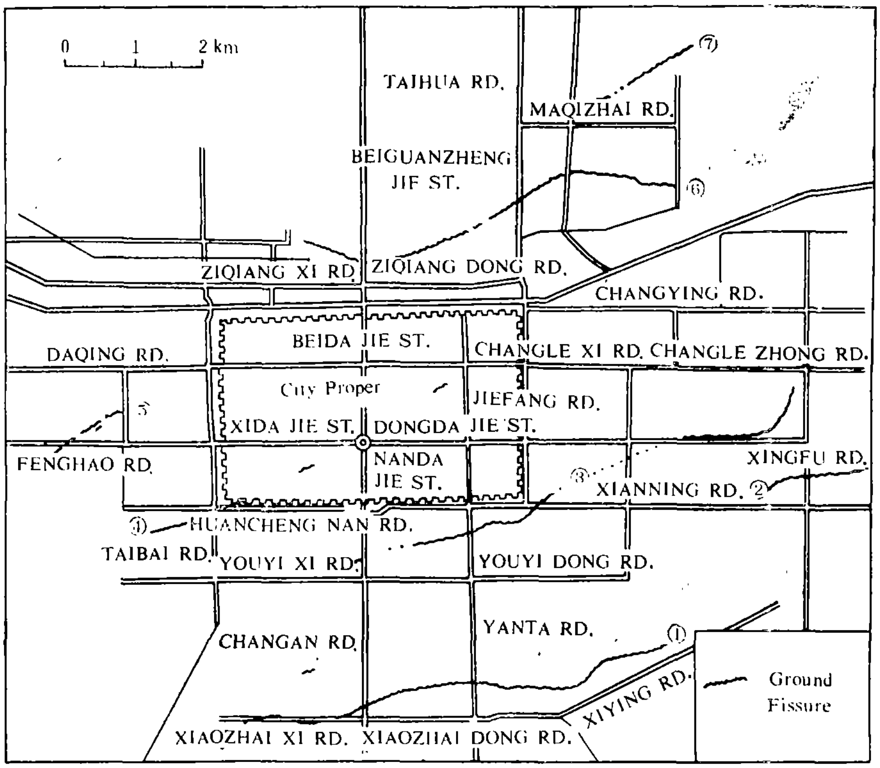

Fig. 1 Distribution of ground fissures in Xi'an City in 1985

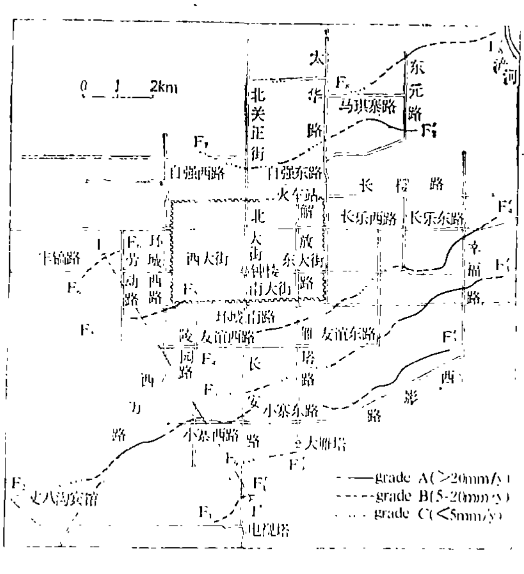

Fig. 2 Distribution of XGF in 1989 and the classification of its vertical slip rate

Ⅰ. The evolution of XGF from 1985 to 1989

1. The total number of ground fissure belts increased from 7 to 9. Fig.1 shows the distribution of XGF in 1985[1], Fig.2 shows it in 1989.

2. The total length of visible ground fissures of XGF increased from 24km to 46km.

3. The intervals between ground fissures decreased from 1—3 km to 0.6—2km.

4. The area where XGF covered increased from 140 sq.km to 150 sq.km.

5. An 'Image ground fissure' occurred in the south boundary of XGF area, which has opposite tilting angle and opposite vertical shear slip, shown in Fig.3 and Fig.4.

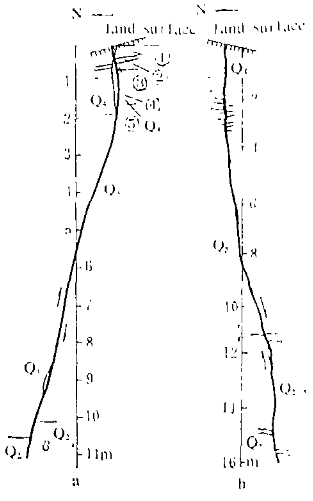

Fig. 8 Comparison of typical trench profile of F2—F8

a. Typical trench profile of F2—F8 (at Xi'an Mining Industrial College)

b. Trench profile of F1 (at the 4th timber supply centre of Xi'an Timber Company)

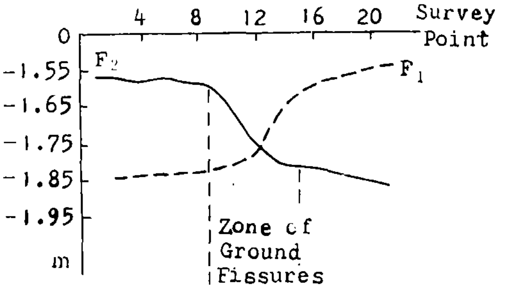

Fig. 4 Comparison of typical height difference curve of F2—F8 to F1

6. The movement of some ground fissures accelerated, while the earthquakes happened in Fen-Wei Basin. The Yuncheng earthquake is shown in Fig. 5 a (M4.3, 1986) and the Datong-Yangyuan earthquake is shown in Fig. 5 b (M5.7, 1989).

7. The movement of some ground fissures accelerated near new land subsidence area which is caused by human activities e.g. large building complex site, extracting ground water etc.. Fig. 6 shows an example.

8. In east part of Xi'an City XGF is more active than in west part. The major movement of XGF is vertical shear slip (average rate is

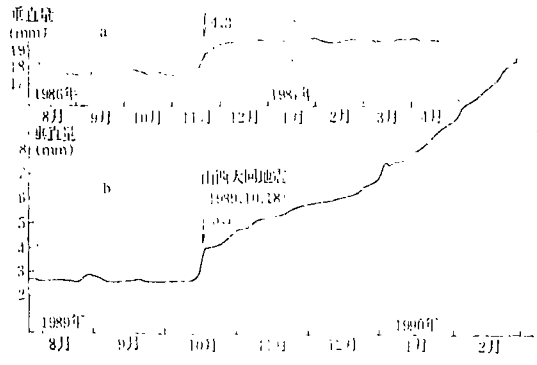

Fig. 5 The slip rate of ground fissure accelerated with earthquakes happened in Fen-Wei Basin
a. The Yuncheng earthquake swarms happened (observation station record at F8)
b. The Datong-Yangyuan earthquake swarms happened (observation station record at F2)

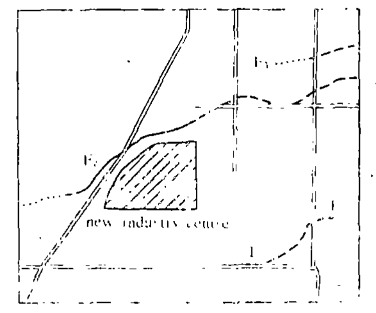

Fig. 6 The slip rate accelerated in a section of F2 near industry centre (at the southwest suburb of Xi'an City)

12—14mm/y.), the second is horizontal tensile movement (average rate is about 4mm/y.), and the third is horizontal shear movement (as small as the error of survey technique). Fig.2 is a map of classification of XGF by its vertical shear slip rate. Refering the classification of active fault, we make XGF into three grades: grade A≥20mm/y; 5mm/y ≤grade B<20mm/y; grade C<5mm/y.

Ⅱ. The tectonic characteristics of XGF

1. The predominant direction of XGF belts in horizontal plane is still near N70°E, which is very similar to the direction of principal compressive stress (near N70°E); the direction of horizontal tensile movement of XGF is very similar to the direction the maximum tensile stress; the latter is obtained by focal mechanism solution, geological and geodetic survey.

2. The fashion of XGF movement is still vertical shear slip and tensile, which is the same as the active fault in Weihe Basin. The 'Image ground fissure' is very similar to the Lintong-Chang'an fault (Fig. 7) which is 7.5km distant to the south of it.

3. In vertical profile of XGF, the deeper a ground fissure dawn (or the older a stratum) the bigger the vertical displacement (Fig.3, Fig.4). We find in our trench date that on the land the average height difference is less than 20cm and the maximum is less than 45cm (in Holocene), but at depth about 10m (in Middle Pleistocene), the average vertical displacement becomes larger than 30cm, the maximum even exceeds 200cm,

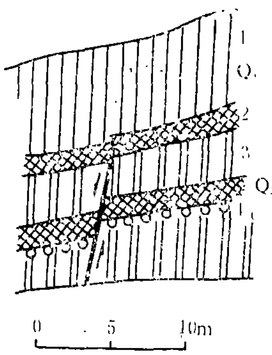

Fig. 7 A Profile of Lintong-Chang'an Fault (at Baopo Village)
1. Late Pleistocene Loess;
1. Ancient Soil Lager;
3. Mid Pleistocene Loess;
4. Calcarous Lump Layer

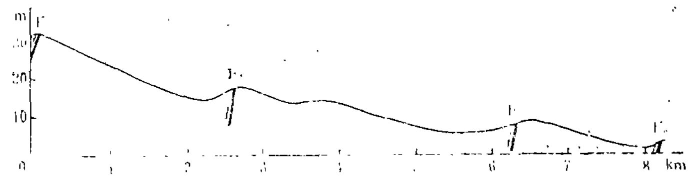

Fig. 8 Topographic feature of XGF (at height curve is along profile I—I' in Fig. 2)*

4. Most of XGF still appear where the topographic feature is the same, the boundary between loess bridge and depression. Usually XGF are on the south slope of a loess bridge (Fig. 8), except fissure 1, the image ground fissure (Exactly, a small section of F1 is usual, but most of it is image ground fissure).

5. The examples which show relation between XGF and earthquakes are not only above (Tangshan earthquake, Fen-Wei Basin earthquakes), but also more. Some scholars think that the slip of XGF may be with quasi-periods which seemingly correlates with the seismic periods in the region[2].

6. The results of chemical analysis of water samples show that the contents of chemical elements F and Sd are much richer in the ground fissure belts than in other places1). It may becomes a new evidence of tectonic movement.

Ⅱ. The artificialness characteristics of XGF

1. Because of overextraction of piezometric ground water (1970-now) Xi'an city has become a special land subsidence region[3]. A comparison of the time, space and intensity features of XGF with the special land subsidence is given as follow.

(1) The formation and development of XGF and Xi'an special land subsidence region were nearl ywithin the same period (1970-now).

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*Based on the survey date of 2nd Survey Brigade of SSB.

1) Northwest Polytechnic University, Study on water quality changes in ground fissure, 1989.

The former followed the latter.

(2) The area of XGF coincides with the area of Xi'an special land subsidence. Although some new ground fissures occur and the total length of XGF is nearly doubled, the area of XGF is still limited in the Xi'an special land subsidence area (about 150 sq.km).

(3) Most of grade A and grade B sections of XGF appear along the gradient belts of ununiform land subsidence. Where a new section of gradient belt has been formed, there is a new section of ground fissure speeding up (Fig. 6).

2. In east part of Xi'an City the condition of overextraction piezometric ground water is heavy, but in west part it is rather slight relatively therefore XGF is more active in east part of Xi'an City than in west, as shown in Fig.2. Especially, the F5 (west suburb ground fissure) almost has been keeping static state for many years.

3. The slip rate of XGF matches the rate of ununiform land subsidence. It can be shown in Fig.9.

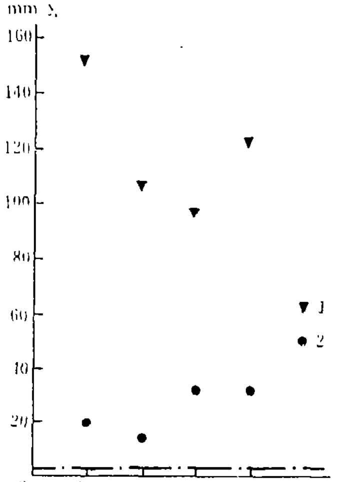

Fig. 9 The rate of land subsidence, vertical slip of XGF and active fault
1. The rate of land subsidence at a special region
2. The vertical slip rate of Lintong-Chang'an fault

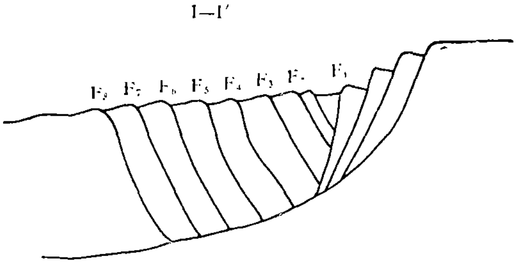

Fig. 10 The tectonic model of XGF (A profile parallel to I—I in Fig. 2)

Ⅳ. The multiple cause mechanism of XGF

1. On the tectonic cause

(1) Tectonic geometrical control function to XGF

This function can be shown in Fig. 10. It is a profile model including XGF and Chang'an-Lintong fault which is a listric normal fault

This model well interprets the geometrical features both of ordinary and image ground fissures.

(2) Tectonic mechanics control function to XGF

The stress concentration belts are formed by tectonic movement shown in Fig. 10. These belts are along the boundary between loess bridges and depressions on land. The friction is decreased in fissures because the tectonic movement makes the static friction become dynamic friction.

When the stress concentration in fissure area goes critical, the tectonic movement can makes a trigger effection to break out the slipping of XGF. Maybe it is why before and after the Tangshan earthquake so many ground fissures occurred.

Tectonic control function can modulate the XGF movement, because it has direct effection on friction coefficient of fissures. It may give a interpretion to the quasi-period feature of XGF which is very similar to seismological period.

2. The artificial causes in forming process of XGF

(1) Many research results show that the overextraction of piezometric ground water makes the layer (200—300m deep) lost pore water and shrink thinner and thinner. It is the main cause of the forming Xi′an special land subsidence region. And the ununiform subsidence makes the vertical slip of ground fissure speed up.

(2) In some cases surface water is out of order, for instance, heavy rain, leaking water from pipe or sewer, it can make fissures movement speed up also, especially in loess area.

(3) The map of classification of the vertical slip rate of XGF (Fig. 2) shows that along each ground fissure the vertical slip rate is changing section by section greatly. It is the artificial causes that make the vertical slip rate change so greatly. Grade A sections and grade B sections show the artificial causes are major, but the grade C sections show the tectonic cause is major.

(4) The artificial causes act on the depth from land surface down the piezometric water layer only. However, the tectonic cause acts on whole depths.

Summary

The XGF is a special movement of ground fracture. The movement is composed of two parts, one is the movement of the second-class fault and another is ununiform land subsidence caused mainly by overextraction piezometric ground water. Because XGF is still moving, the situation is rather severe we should not only study its complicated causes, but also research feasible precautions against the catastrophe.

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西安地裂缝的新活动及其机制的初步研究

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摘 要

本文给出了西安地裂缝的新活动图象（1985—1989）并进行了分析，指出了西安地裂缝的构造特征及人文特征。对于构造特征，本文提出了不仅有构造的几何控制作用，而且有构造的力学控制作用。前者直观地表现在地裂缝的空间几何分布规律上，而后者则既表现在地裂缝的形成过程中，又表现在地裂缝活动与地震活动的时间特征上。人类活动主要是过量抽取地下承压水所导致的地面不均匀沉降，这是地裂缝运动速率比构造运动速率高一个数量级的原因。按照地裂缝的主运动即垂直差异运动速率，本文将地裂缝分为三个等级（A级≥20毫米/年，5毫米≤B级＜20毫米/年，C级＜5毫米/年）。西安地裂缝的活动度分级图较好地反映了地裂缝的多因迭加机制。