中国活断层研究专辑

祁连山-河西走廊活动断裂系

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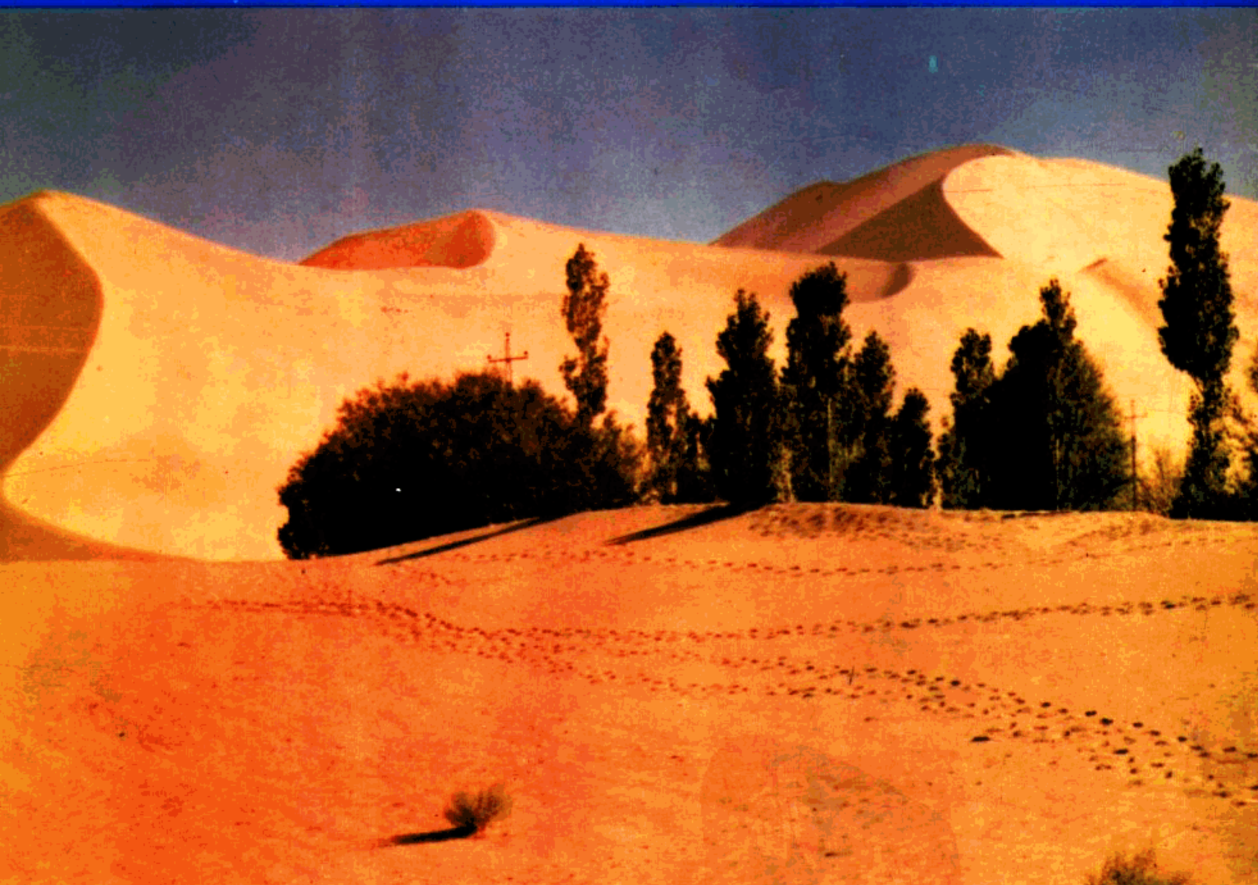

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序

活动断裂是现代构造活动的重要表现。作为世界屋脊的青藏高原的隆升是最近地质时期的产物，现代构造活动十分突出，是我国、乃至全球主要地震活动区之一，祁连山-河西走廊地区正是青藏高原北界的一部分。这一条边界构造带西起西昆仑山山前，经过阿尔金断裂带、祁连山-河西走廊构造带，向东延至海原-六盘山-宝鸡构造带。虽然沿这一复杂边界构造带不同地段的运动性质还有所差别，但强烈的现代活动是其共性，它们都具有高的断裂滑动速率、短的古地震重复周期、众多的现代大地震分布。所以，这一活动构造系成为我国活动断裂研究的主要对象，本书就是对这一活动构造系的主要研究成果之一。

祁连山-河西走廊活动断裂系位于青藏高原北缘中段，南为高耸的祁连山，山前断裂结构复杂，现代活动十分活跃，其北部为河西走廊断陷盆地带。由于青藏高原的北东向挤压和高原向南东方向的滑动，带内的北西西向断裂和断陷盆地带都表现为左旋走滑和挤压逆冲性质。本书以丰富的资料，全面系统地论述了这一构造带的几何学及运动性质，使这一个十几年前曾引起争论的问题终于获得了解决。不仅如此，作者们还进一步研究了这一断裂系的时、空演化历史，特别是新生代和第四纪以来的演化历史，并着重指出早、中更新世之间似乎是断裂系活动性质发生重要变化的时期。此前，断裂系表现出强烈的挤压，此后，沿断裂的走滑活动更加突出，直到现代。从海原断裂带和本断裂系的演化来看，这一问题在青藏高原地区也许具有普遍意义，应该引起注意。

在活动断裂运动学定量研究方面，本书通过断错地貌和地质及其年代学研究，详细地阐明了带内主要活动断裂晚更新世或全新世的滑动速率。在断裂运动方式研究方面，本项研究特别注意了断层岩，包括断层泥的成分、结构、厚度及断层泥中矿物颗粒的光学特性和表面形态特征研究，结合围岩成分和大地震及地表破裂分布对这一断裂系内的主要活动断裂或不同断裂段的蠕滑和粘滑特征进行了分析和划分。这正是本书的特色之一。断层的蠕滑和粘滑方式在美国圣安德烈斯断裂带上表现十分清楚，但对我国大陆内部活动断裂而言，这一问题的研究尚是一个薄弱环节，作者们在这方面的工作是一次十分有益的尝试。

本书还详尽地研究了这一活动断裂系内发生的 5 次 7 级以上大地震所形成的地表破裂带及其与活动断裂的关系，进一步论证了它们是带内活动断裂现代破裂和错动的结果。这也说明了断裂的现代活动和晚第四纪活动的一致性及活动断裂研究的重要性。

作者们利用槽探、断层崖剖面形态变化和断裂滑动速率等不同的方法研究了祁连山-河西走廊断裂系内主要活动断裂的全新世古地震及大震重复间隔，获得了一批可贵的定量资料。根据这些资料，本书还着重讨论了大震重复间隔的不均一性问题，认为本区 12000 年以来存在 3 次古地震和地震的超长活跃期(为了与一般历史地震活跃期相区分，我们针对古地震研究发现的大地震相对集中时期使用了这一名词)，在每个超长活跃期内，大地震的重复间隔是很短的，目前本区仍处在这种超长活跃期的第Ⅲ期之中，所以，本区的大地震危险性不容忽视。值得指出的是，在古地震研究中，本书对逆断裂型断层崖扩散方程及复合型断

层崖多次位错事件的分辨提出了新的计算模式，其思路和方法都是先进的。

为了确定断错地貌面的年龄，作者们采用了灰岩砾石溶蚀速率法，建立了研究区年龄量版曲线。这一新的相对测年方法的建立对在干旱、半干旱地区研究活动构造和新构造有很重要的意义和广阔的应用前景，因为，一般而言，在这样的地区是很难获得有机炭样品来测定其绝对年龄的。

可贵的是，作者们还利用获得的活动断裂资料对本区的潜在震源区进行了研究和新的划分，并对近期地震危险性进行了评估。重要的是，在作者们所指出的两个近期 6.5—7 级地震危险区内，已经于 1990 年 10 月 20 日发生了天祝、景泰 6.2 级地震。

由于祁连山-河西走廊活动断裂系既具有左旋走滑特征，又是一条挤压构造带，所以，这里是研究走滑-挤压构造的良好场所。本书在这方面也进行了有益的尝试，并结合本区的构造应力场特征，对祁连山-河西地区的压陷盆地、逆断层的类型和形成机制、以及地壳动力学问题进行了讨论。

本书既是一部关于活动断裂的综合专题研究成果，也是祁连山-河西走廊地区第一部活动断裂研究专著，内容丰富，资料翔实，无论在理论和实际应用上都有重要价值。

中国活动断裂研究专辑反映的是我国近年来在活动断裂研究方面取得的最新成果，本书即是这一专辑中的一本。我们期望专辑和本书的出版能对活动断裂及其相关研究工作起到推动作用，并在实际应用中发挥越来越重要的效果。

邓起东

1991 年 12 月

The Qilian Mountain–Hexi Corridor Active Fault System

Abstract

The Qilian Mountain–Hexi Corridor active fault system is located in the Qilian Mountain and the Hexi Corridor region, Gansu Province, northwestern China. The fault system consists of three major active fault zones and an active structural basin belt, the northern Qilianshan fault zone, the Changma–Ebo–Maomaoshan fault zone, the northern Longshoushan fault zone, the southern Longshoushan fault zone,and the Hexi Corridor structural basin belt. In order to study the geometry, kinematics, and evolution of these fault zones, other fault zones in the vicinity of the region are also concerned, such as the Altun fault zone.

The northern Qilianshan fault is the focus of this book. The fault is present north of the Qilianshan Caledonian folds and thrust belt. Together with the Hexi Corridor structural basin belt, they form a transition zone from the stable Alashan block to the active Tibet Plateau. The fault zone consists of a series of NWW–trending faults. From west to east they are the Hanxia–Dahuanggou fault, the Yumen fault, the Fodongmiao–Hongyazi fault, the northern Yumushan fault, the Minle–Damaying fault, and the Huangcheng–Taerzhuang fault. In addition, there is a group of NNW–trending fault. They are the Jiayuguan fault, the eastern Yumushan fault, and the Wuwei–Tianzhu fault. The Changma–Ebo–Maomaoshan fault zone is parallel to the northern Qilianshan fault. Its tectonic activity, age of formation, and style of deformation are similar to the northern Qilianshan fault zone. Other fault zones in this region, such as the northern Longshoushan, southern Longshoushan, and the Altun fault zone, closely relate to the northern Qilianshan fault zone.

The Qilian Mountain–Hexi Corridor active fault system is a major active fault system in the northern Tibet Plateau. The uplift of Tibet Plateau is a significant tectonic event during neotectonic evolution of northwestern China. The uplift significantly controls and influences modern tectonic movement and geological evolution around the plateau. Paleontological and geomorphological studies indicate that the plateau started to uplift in Pliocene and the elevation of the plateau was about 1000 m above sea level by then.The plateau is significantly uplifted in Quaternary. The differential movement of the plateau with respect to its vicinity is intensified. The great historical earthquake around the plateau is the testimony of this differential movement. Studies of active faults bounding the Tibet Plateau are very important in understanding not only the behavior of these faults, but also the deformational process of the plateau.

The collision and northward penetration of India into Eurasia cause uplifting and

northward motion of the Tibet Plateau. The Qilianshan and Hexi Corridor region is located in northern part of the plateau. The Alashan block north of the region is a stable block, and probably resists northward movement of the Tibet Plateau. This special tectonic setting creates intensive compression and crustal shortening in the Qilianshan and Hexi Corridor region. On the other hand, the Tarim basin also resists the northward motion of the Tibet Plateau, and the convergence between them is transfered into left-lateral shear along the fault: The Qilian Mountain and Hexi Corridor region also subjects to left-lateral rotation under the influence of the Altun fault zone. Thus, the Qilianshan and Hexi Corridor region subjects both compression and left-lateral shear. Most of active fault studies in the past are on strike-slip and normal faults. Active reverse faults are not well studied. This book in some extant fills the gap on this subject, and has important meaning to geometry, kinematics, and seismic behavior of reverse faults.

Under the organization of the State Seismological Bureau, Institute of Geology and Lanzhou Institute of Seismology carried out active faults and earthquake recurrence study in the Qilian Mountain-Hexi Corridor active fault system from 1985 to 1989. The study includes Tertiary and Quaternary tectonics, fault gouge, geometry and kinematics of active faults, fault slip rate, surface ruptures associated with historical earthquakes, paleoseismicity, earthquake recurrence, and active faulting and dynamics of the Qilianshan and Hexi Corridor region. The method includes interpretation of satellite image and aerial photo, tracing and transecting active faults, geological mapping of sections of active faults. We use stratigraphic comparison, ^{14}C, thermoluminescence, compound fault scarp, solution fissures on limestone pebbles methods to date Late Quaternary sediments. This project is a part of cooperation between France and China on seismology and active faults study. The scientists that participated in this study from France are P. Tapponnier, G. Peltzer, Y. Gaudemer, B. Meyer, of Institute de Physique du Globe de Paris, and Chi Trach Hoang of Centre des Faibles Radioactivete, France. Some of the results presented in this book are obtained by both Chinese and French scientists. The cooperation have greatly promoted studies of active faults in this region.

This book discusses active faults, fault gouge, earthquake surface ruptures, paleoseismicity, earthquake recurrence interval, fault mechanics, and style of Quaternary deformation based on new data and new ideas obtained during the field investigation. For example, outcrops of active fault have been found in Early, Middle, and Late Pleistocene, and Holocene stratigraphy, their attitude, pattern, sense of motion, and timing of activity are the bases for analysing geometry, kinematics, and evolution of the active fault system. many stream offests and fault scarps provide important information of displacement per event, slip rate, and earthquake recurrence. Field investigation also reveals aboundent paleoearthquake evidence, such as scarps, colluvial wedges, fissures, depressions, mole tracks, and stream offsets associated with paleoearthquakes. Surface ruptures associated with historical earthquakes are testimony of modern deformation. During the field investigation scarps associated with 180

Biaoshi earthquake are discovered, and additional 20 km surface rupture zone, from Hongxianxian to Majiaai, is found to be associated with the 1932 Changma earthquake. Field studies have obtained new information about Late Quaternary tectonic activity along the Leigongshan–Maomaoshan fault. The Tianzhu basin within the northern Qilianshan fault is structurally a pull–apart basin. The new results of our investigation also include discoveries of different fault gouge that reflects strick–slip and creep–slip respectively, different geometry of active reverse faults, different solution fissures on limestone pebbles on geomorphic surfaces of different age, slickenshdes on surfaces of Quaternary faults that can be used to structural analysis of regional stress field.

This book is the main results of our five year study on the Qilian Mountain–Hexi Corridor active fault system, that is centered on Late Quaternary active faulting, large earthquake recurrence, application of seismotectonic criteria to seismic risk assessment, and mechanism and dynamic model of compressional structures. In order to clearly present the central subjects, some other subjects are also described. The book describes the regional tectonic setting of the Qilian Mountain–Hexi Corridor active fault system at first, including stratigraphy, structure, igneous activity, and tectonic evolution. To relate active faults to earthquake activity, there is a chapter in the book to discuss seismicity of the region. The discussion includes identification of seismic zone, distribution of earthquakes, earthquake history, migration and gap–filling of earthquake, and the future seismic risk.

The book discusses Late Quaternary activity of the northern Qilianshan fault zone in detail. Every secondary fault of the fault zone is described with aboundent evidence of tectonic activity shown by cross–sections, maps, and pictures. These faults are the bases of studying Late Quaternary activity of the fault system. Both vertical and horizontal displacements along fault within the fault system are measured. To obtain distribution of slip rate along the fault zone, slip rate along each part of the fault zone is calculated. The result clearly shows the variation of slip rate along the fault zone. The slip rate also varies with time.

Of the important problem in calculating slip rate is the age of Late Quaternary sediments that relate to offset history of the fault. The region is an arid area, and has very poor vegitation coverage. The ^{14}C sample is very difficult to obtain. In spite of stratigraphic comparison and thermoluminescence dating method, the method of solution fissures on limestone pebbles is established to date Late Quaternary geomorphic surfaces. This method is a statistical method assisted by laboratory experiments. The method consists of three steps, first to establish the local solution depth–age relation curves, second to measure the solution depth on pebbles from geomorphic surfaces of unknown age, and then to fit the age relation curves to obtain the age of respective geomorphic surfaces. This method still needs to be improved, but it is first established during our study on the Qilian Mountain–Hexi Corridor active fault system.

Our studies of the Qilian Mountain–Hexi Corridor active fault system also include microstructure of fault gouge. The purpose is to identify evidence of strick–slip and creep–slip from microstructure. Sampling and analysis indicate that some faults with high slip rate have no large historical earthquake. Creep–slip probably dominates the style of deformation along these faults. Historical large earthquakes often occurred along the faults with high slip rate and predominant strick–slip movement. The result of this study can be used to identify the potential seismic source area.

Paleoseismicity is one of important subjects during our study. Field investigation reveals paleoseismic evidence along all active faults associated with historical earthquakes. The recurrence interval of large earthquakes in the fault system is estimated by three methods. The first is to estimate the average recurrence interval using average slip rate along respective fault. The second is to directly identify and dating paleoseismic events from the trench, and to obtain recurrence interval from geological records. And the third is to estimate the recurrence interval through the relation between the height and the slope angle of the fault scarps. All of these three methods have been used in our study on the Qilian Mountain–Hexi Corridor active fault system. The results are important bases in assessing the future seismic risk and in identifying the potential seismic source area.

Previous studies on fault scarps are mainly on normal faults. Scarps of reverse fault are well developed in the Qilian Mountain–Hexi Corridor region. Based on analysis of evolution of the reverse fault scarps, we have established the mathematic model of reverse fault scarp, and calculated the diffusion equation and mass diffusivity K. This can be used to estimate the age when the scarp was formed.

There are several large earthquakes occurred in the region. Surface ruptures were associated with these large earthquakes. Our study indicates that structural pattern, sense of motion, and style of deformation of the surface ruptures are similar to the geometry and kinematics of the northern Qilianshan fault zone. The surface ruptures are the manifest of the modern activity of the fault zone. They are also important in understanding earthquake mechanism and in quantitating the seismotectonic criteria.

The identification of potential seismic source area is very important in seismic risk assessment. Our study on this subject uses seismotectonic criteria together with seismological and geophysical data to identify the potential seismic source and to assess future seismic risk.

The book discussed regional stress field based on microstructural analysis, seismotectonics, focus mechanism, and geodetic data. Because the region is a compressional region, we have emphasized the geometric patterns of reverse faults, that include imbricated reverse faults, listric reverse faults, compression–induced reverse faults, planar reverse faults, stepped reverse faults, and antithetic reverse faults. The basins in the region is also of compressional origion, such as the toward–thrust basins, compressional basin, imbricated basin. The formation and geometry of these basins are closely related to crustal shortening of the region. Based on regional tectonic setting and Late Quaternary activity of the Qilian Mountain–Hexi Corridor active fault system, we discussed dynamic model of the Qilian Mountain–Hexi Corridor region and its vicinity. The results are important in understanding modern tectonic activity in northern part of the Tibet Plateau and its influences and controls on surrounding regions.

The following geologists participated in this study: Guo Shunmin, Xiang Hongfa, Huang Zhao, Yin Kelun, Ji Fengjiu, and Li Bodong from Institute of Geology, State Seismological Bureau; Chen Zhitai, Xiang Guangzhong, Cai Shuhua, Dai Huaguang and Zhou Jinchang from Lanzhou Institute of Seismology, State Seismological Bureau. The book is written by above people. Guo Shunmin, Chen Zhitai, Xiang Hongfa, and Dai Huaguang are editors of the book.

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