PRELIMINARY RESULTS ON THE GEOMETRY AND KINEMATICS OF THE YINMENKUONG-GUOCHENG SEGMENT ACTIVE NORMAL FAULT. YIANQING BASIN, BEIJING, CHINA

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A B S T R A C T

Field studies along a segment of the Langshan-Huangbaisi fault zone lead to a description of the geometry and kinematics of this fault. Although the general strike of the zone is NE-SW, the study segment trends E-W. It deviates to NE-SW and to almost N-S direction in its easternmost edge, while it is possible that follows the pre-existing system of joint structures. Numerous mesofaults and related fractures, showing recent activity, were identified along this fault. Most sites of the studied area are extensional brittle structures. The quantitative stress analysis of recent faults affecting mid-late Pleistocene and Holocene fans and screes results an extensional stress field having a N-S trending σ_3 axis. Although this N-S extension clearly dominates on the faulting, some other extensional tectonic features are also present, indicating an E-W to ESE-WNW trending extension.

ΠΡΟΔΡΟΜΑ ΑΠΟΤΕΛΕΣΜΑΤΑ ΓΙΑ ΤΗ ΓΕΩΜΕΤΡΙΑ ΚΑΙ ΚΙΝΗΜΑΤΙΚΗ ΤΟΥ ΕΝΕΡΓΟΥ ΚΑΝΟΝΙΚΟΥ ΡΗΓΜΑΤΟΣ YINMENKUONG-GUOCHENG. ΛΕΚΑΝΗ YIANQING ΠΕΚΙΝΟ. ΚΙΝΑ

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Π Ε Ρ Ι Λ Η Ψ Η

Παρατηρήσεις υπαίθρου κατά μήκος του τμήματος Yinmenkuong-Guocheng της ρηξιγενούς ζώνης Langshan-Huangbaisi χρησιμοποιούνται για να καθορίσουν τη γεωμετρία και κινηματική αυτού του ρήγματος. Αν και η γενική διεύθυνση της ζώνης είναι ΒΑ-ΝΔ, το τμήμα του ρήγματος που μελετήθηκε έχει παράταξη Α-Δ. Στο ανατολικό του άκρο αποκλίνει προς ΒΑ-ΝΔ και σχεδόν Β-Ν διεύθυνση. Είναι πολύ πιθανό να ακολουθεί τη δομή του προϋπάρχοντος συστήματος διακλάσεων. Η ποσοτική ανάλυση τάσεων των πρόσφατων ρηγμάτων που επηρρεάζουν μέσο-ύστερο πλειοκαινικά και ολοκαινικά ιζήματα, δείχνει ένα εφελκυστικό πεδίο τάσεων με Β-Ν διεύθυνση του άξονα σ_3. Αν και αυτός ο Β-Ν εφελκυσμός σαφώς κυριαρχεί κατά μήκος του ρήγματος, άλλες εφελκυστικές δομές δείχνουν επίσης ένα δεύτερο Α-Δ εφελκυσμό.

INTRODUCTION

North China is referred in terms of tectonics as Sino-Korean Paraplatform (Huang 1960) or "diwa", meaning geodepression (Chen 1988), and Sino-Korean block (Hsu et al. 1990, fig.1a). It consists mainly of proterozoic-palaeozoic formations and some mesozoic intrusions. The pre-Cenozoic history is marked by the successive accretion of continental blocks and terranes, with intervening sutures reactivated in the Cenozoic. Since late Neogene North China block was subject of a new tectonic process. It has been segmented into sub-blocks, bounded by major and smaller scale faults. Thus, from a neotectonic and seismotectonic point of view North China could be divided into some main intraplate blocks as: a) the rigid northern one (Yanshan Mts), b) the subrigid central block (Taihangshan Mts), c) the western rigid "Ordos" block, surrounded by major active faults; and d)the eastern great cracked block, that is mainly the North China plain (Lu 1989). Pliocene-Quaternary Shanxi rift system separates blocks b (Taihang Shan Mts) and c (Ordos). Much of the neotectonic deformation in North China occurs along wrench zones, where it is accomplished by synthetic and anti-thetic strike-slip and normal faults. The northern - northwestern mountainous region has experienced rather low level activity. In contrast, the plain shows a higher seismic activity (fig. 1b).

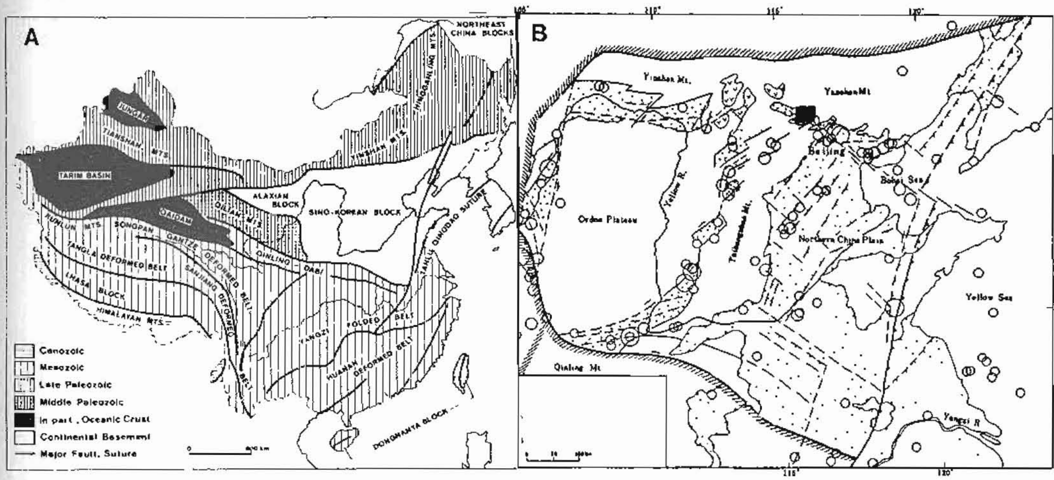

Fig.1. A) Tectonic subdivisions of China (main blocks) after Hsu et al., (1990). B) Main tectonic structures of the Sino-Korean block. Faults of various orientations cross the block, with typical rhombic or orthogonal sub-blocks. The NNE-SSW ones dominate the region, in the east (Beijing-Hebei plain) and the Shanxi Rift system and Ordos platform in the west (Lu 1989). Black box shows the study area.

Since most continental earthquakes, are caused by strike-slip faults with shallow depth, historical and instrumental epicentres of the broader area are distributed along NW-SE and NE-SW belts (seismotectonic structures), (Ma 1987, Ma et al., 1989).

The study area belongs to the eastern block and lies at "eastern block"-"northern rigid block" boundary. According to Xu Xiwei et al. (1992, 1993) it belongs to the northern edge of the Shanxi Rift system. It extends along the intramountain Yanqing basin. In the Yanqing basin, sedimentation commenced already during Miocene (X.Xu and X.Ma, 1992), but it is mainly filled up with Quaternary deposits (middle-late Pleistocene - Holocene). Yianqing basin is characterized by an asymmetric development (elongated NE-SW, semi-graben structure). Recent sediments, which indicate the age of tectonic events, are mainly lacustrine deposits, fluvial and alluvial fans, as well as aeolian sediments.

The northwestern marginal fault of the Yanqing basin is known as Langshan - Huangbaisi active fault zone, lying 60-80 km NW of Beijing (fig. 2a). Haituo mountains constitute the footwall (upthrown side) and the basin the hanging wall (downthrown side).

The general strike of the 35 km long Langshan - Huangbaisi active fault zone is NE-SW, while it is clearly divided into three independent segments trending NNE-SSW, NE-SW and almost E-W. (Cheng et al., 1991a).

The present level of seismicity is low, but field morphotectonic and palaeoseismological observations and measurements show that the fault system was very active during the whole Quaternary and especially Holocene times. Hence, the available data are not really sufficient to give a balanced view of current activity.

This paper describes one distinct fault segment in particular, known as Yinmenkuong - Guocheng (fig. 2b). The aim of the present work is to reconstruct the orientation of Quaternary, if not late Cenozoic, stresses using measurements of sets of minor striated faults, tension gashes and joints.

FAULT GEOMETRY

Field data comprise measurements of faults (strikes - dips including slickenside lineations), tension fractures and joints in about 12 sites, as well as fault traces mapped in scale 1:50,000.

The main morphological and tectonic features of the study fault are described below. The main trend of the fault is E-W (N90°/70°), while some fault planes with different strikes cut each other at acute angles. There is an association between the NW-SE and E-W trending faults, in the sense that they represent the strike variations of the same fault slip plane. In general, the main fault shows a linear arrangement locally forming weak zigzag pattern and "en echelon" or step pattern (see fig. 2b, point I). The only remarkable deviation is that of the eastern edge (fig. 2b, point III), where a NE-SW branch affects the basement, showing clear young morphotectonic features. It seems to be the active branch, while the rest E-W trending part of the fault looks inactive with no clear morphotectonic features.

The majority of the faults present pure dip-slip motion, while a relatively smaller number of oblique and strike-slip fault surfaces are present too. Along the main faults a main vertical component of motion as well as a 10°-30° tilting of the layers in the hangingwall with dips opposite to the fault, has been observed. The tilted small blocks are displaced by small faults and fractures parallel to the main fault, while some secondary ones strike obliquely or approximately perpendicular

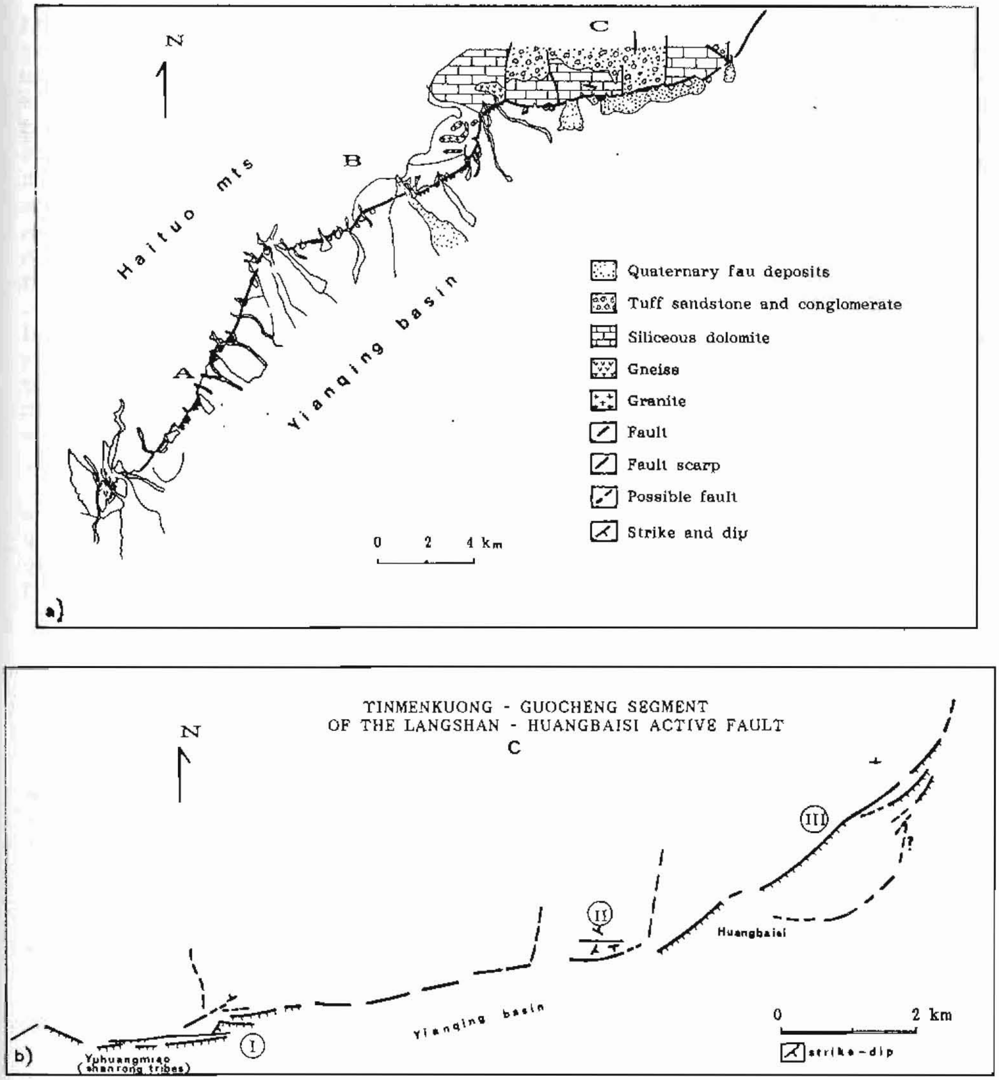

Fig.2. a) The Huangbaisi-Langshan Fault Zone, which bounds the northwestern margin of the Yianqing basin. NW block is the upthrown (footwall) side and the SE block is the downthrown (hangingwall) side, where quaternary sediments and especially middle late Quaternary fan deposits extend. Segments A, B, and C are shown. b) The enlarged area is the Yinmenkuong-Guocheng segment (C).

to the main fault. This phenomenon has been observed mainly along the eastern part of the study fault in the zone affecting formations of the substratum.

METHODS USED IN STRESS ANALYSIS

The importance of estimating paleostress from faults and their kinematic indicators has been known for many years. Among the known methods for determining the neotectonic-active stress pattern, the following methods have been used (fig. 3): The Right-Dihedrons (Angelier and Mechler 1977) an empirical method similar to earthquake focal mechanism and the Mean Best Stress Tensor (Carey and Brunier, 1974; Angelier, 1979) for a given fault population. The key to the reconstruction of the principal stress axes are mainly the slicken-lines (striae), assuming that motion on each fault is independent and occurs in the shear direction governed by a single common mean stress deviator. The Caputo and Caputo (1988) methodology is a mathematical approach (minimization technique) called Conditioned Square Minima Method applied to previous Right Dihedrons and P/Taxes methods (computing programme FAULT). These methods consist of determining the best fitting reduced palaeostress tensor for a given fault-slip data set, thus identifying the attitudes of three principal stress axes (maximum compressional stress σ_1, intermediate stress σ_2, and minimum stress σ_3).

Also, in order to complete the estimation of the stress tensor, systems of tensional fractures or joints affecting mainly recent sediments, have been used. A numerical methodology (Computing programme JOINT, Caputo 1991) following Hancock and Engelder (1989) assumptions, has been adopted.

GEOLOGICAL REGIME

Palaeostress analysis of the western part of the segment.

Figure 4 shows a sketch of an artificial outcrop (palaeoseismo-logical trench) along the main active fault, at the Shanrong tribes cemetery (Eastern Zhou Dynasty) site. Quaternary deposits are in contact with the very fractured bed-rock (dolomites mainly) and the early Pleistocene(?) cemented conglomerates and dolomite-limestone debris. Recent sediments are of late Pleistocene and Holocene age including historical ones. Striated fault surfaces from this trench, as well as from the broader area of the Shanrong tribes cemetery have been used, in order to detect the active stress orientation. A NNE-SSW ($\sigma3$ N193°/7°) direction of extension has been calculated, while a system of conjugate tension fractures (joints), more or less orthogonal, affecting the hole series of the Quaternary sediments help to confirm this orientation of extension.

A similar example of recent - active fault stress analysis arises from a second trench, which is shown in figure 5. The trench excavated across the scarplets of a "graben" within the recent fan deposits. Faults and tension fractures affecting only young sediments are due to the recent, if not active, stress regime (NNE-SSW σ_3: 190°/14°).

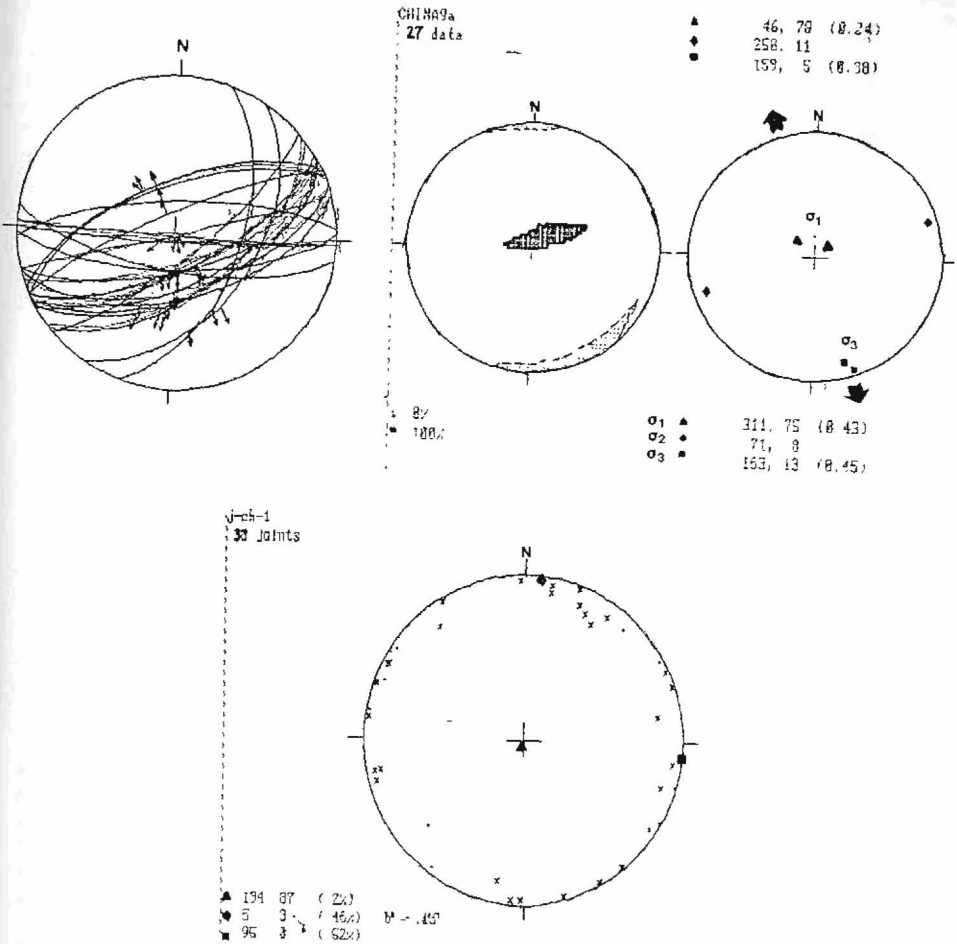

Fig.3. An example of fracture data and stress calculation (A) Analysis of fault-slip data sets. In the top left stereonet are presented the faults (as curves) and striae (as arrows). Centre, the results of the right-dihedrons method (Angelier and Mechler, 1977). Areas of 100% and 0% of probability to contain the two principal stress axes σ_1 and σ_2 are shown. Top right net: the results of the numerical methodology of Caputo and Caputo (1988) applied on the right-dihedrons and P/T axes methods and the Carey's (1976) "mean best stress tensor" method. σ_1:triangles, σ_2: rhombs, σ_3:squares. Stereonets are Schmidt's stereographic projections of lower hemisphere. (B) Down right: analysis of joint systems (Caputo, 1991) affecting Quaternary red beds. Crosses represent the poles of the measured joints, while different size crosses show different normal relative movement. Triangles, rhombs and squares represent the σ_1, σ_2 and σ_3 axes respectively.

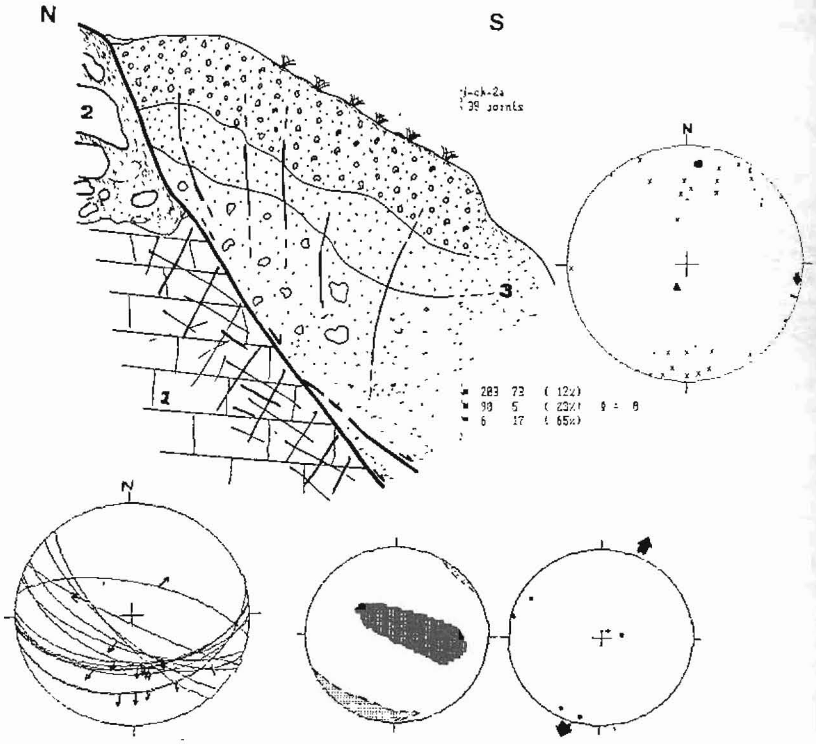

Fig.4. A sketch of an outcrop along an artificial trench close to Zhu dynasty cemetery. 1) Hihg fractured substratum (dolomite), 2) Cemented Conglomerates and debris (upthrow block), 3) Quaternary debris (downthrow block). Black heavy lines represent synthetic and antithetic joints affecting the quaternary deposits. Down stereonets: data and stress results from this site and the broader Yuhuangmiao area. Large black arrows indicate computed directions of extension. Top right: stereographic projection of joint poles and the calculated stress (or strain) principal axes. Symbols as in figure 3.

Morphotectonics, Structure and stress pattern along the central part of the segment.

Typical fault scarps of high slop angles and relatively small height, extend in quaternary deposits, whereas degraded scarpcrests exist in bedrock. These structures, help in mapping the main active fault and the secondary ones. The interaction between normal fault scarps and geomorphic surfaces, such as fluvial terraces has been also recognized. A characteristic feature where faults control the drainage orientation and pattern has been described previously. Figure 6 shows this typical example of stream deviation in a more complex area, where the main fault trace stops and some parallel branches continue as steps. Yianqing faults offset Quaternary deposits and thus permit to evaluate the age of their reactivation (Pleistocene-Holocene). The existence of such morphologic features implies that it is an active structure. (Cheng et al., 1991a, b). The measured faults and joints are presented in figure 3. The results of this stress analysis show that the principal stress (strain) axes are : σ_1 almost vertical (N46°/80° or N311°/75), σ_2 ENE-WSW trending, horizontal and extensional (N250°/11° or N70°/8°), and σ_3 NNW-SSE trending horizontal (N160°/5° or N165°/13°).

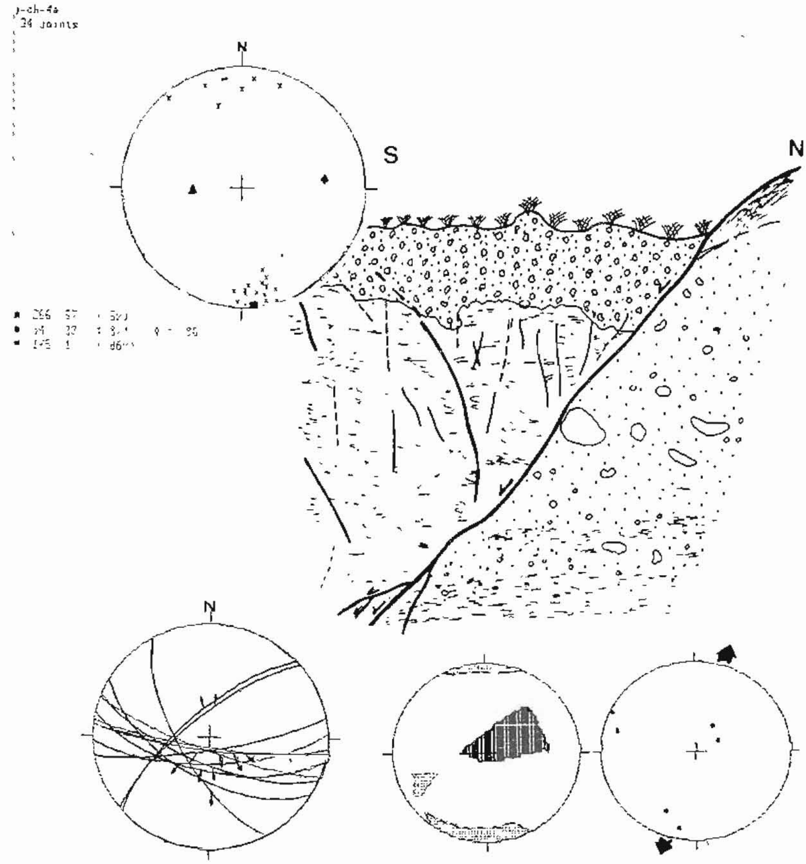

Fig.5. A fault affecting quaternary fan deposits along a young fault scarp. Sketch from a palaeoseismological trench. Results of stress analysis as in figure 4.

Deformed pebbles within the fault zone.

The joints are considered to be plate tectonic signatures and more specific neotectonic ones (Scheidegger, 1993). There is an ongoing argument whether the joints are extension joints (Hancock and Engelder, 1991), or shear joints (Scheidegger, 1993). In the following evaluation it is accepted that joints are extension structure.

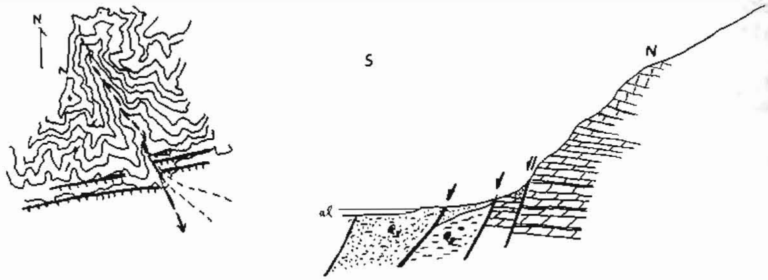

Fig.6. Detailed map of a characteristic step fault geometry Left: fig.2b point I and the stream offset (heavy line with the arrow is the youngest branch). Right: A cross section showing faults affecting both bedrock and late Quaternary deposits (Q_2, Q_3 and al).

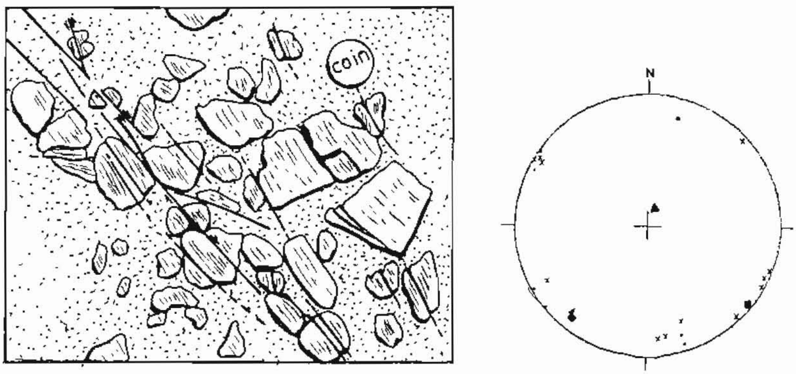

Fig.7. Sketch drown in the field showing deformed hanging-wall recent conglomerates. The fractured pebbles displaced by homogeneous shear planes demonstrate a normal movement. Right stereonet shows the measured plains and the calculated direction of extension (σ_3: N128°; σ_2:N218°/11, φ=0.36).

In some sites of measurements, and especially within conglomerates some fractured or dislocated pebbles are present. In an outcrop of very recent conglomerates deposited on the hanging wall of the main fault, some sheared pebbles demonstrate a normal movement while the majority are extensional joints. Figure 7 is a sketch drown in the field, showing the deformed pebbles. Pebbles have fractured by tension gashes or joints. All these have been considered as joints during data elaboration. The corresponding stereonet shows the poles of the measured fractures and the orientation of extension (NW-SE).

CONCLUSIONS ON THE FAULT KINEMATICS.

Little information is available in the literature concerning the neotectonic stress pattern of North China. The recent-active regional stress regime of North China is NE-SW direct compression (σ_1) and NW-SE extension (σ_3) (e.g. Scheidegger, 1985; Ma et al., 1989; Xu, X. and Ma, X., 1992). It is also the first time that a stress analysis study from fault slip data was carried out in Yianqing area. The present study results indicate that stress tensor computations by the above mentioned methods, sufficiently document a N-S trending extension for each site. It averages from site to site between NNW-SSE and NNE-SSW. Using the directions of the σ_3 of all sites of measure-ments an average value 183°/18° has been computed. This N-S extension seems to dominate the area. Geological and geomorpholo-gical arguments indicate that study faults have been reactivated during middle-late Pleistocene and Holocene. But a second E-W extension has been documented through the calculated extensional σ2 axes , the joint systems, as well as by the striated faults within the fault zone in bedrock (fig. 8). It could be considered as an older extensional phase or as a simultaneous secondary one.

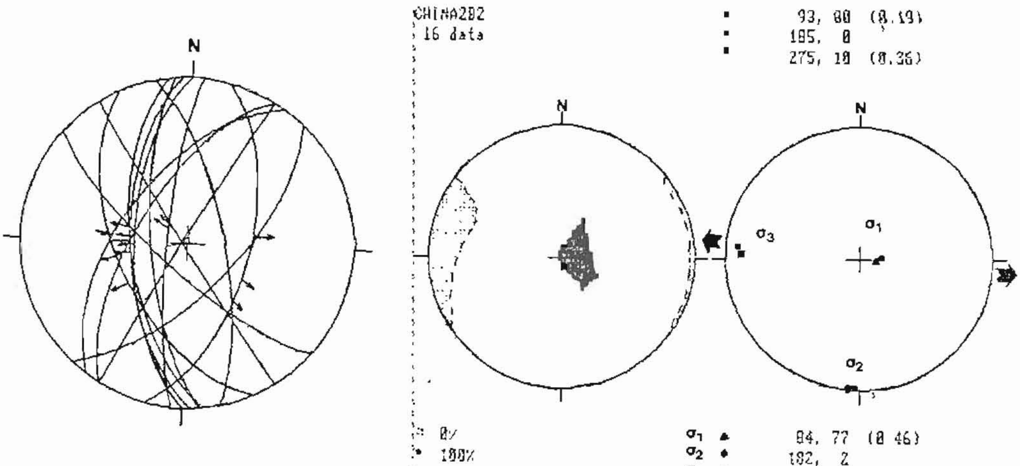

Fig.8. An example of E-W trending extension (σ_3) as deduced from conjugate and semi-conjugate faults (A); from joints (B); within the main fault zone (mesozoic red beds).

Yanqing basin may be related to the evolution of the NNE-SSW and NW-SE WNW-ESE trending faults underlying of the North China. NE-SW, trending faults are generally dextral, transtensional sets, while NW-SE ones are conjugate sinistral systems (X.Xu and X.Ma, 1992). On the other hand, north China block is believed to be a Palaeozoic or pre-Palaeozoic platform. The term platform is used here in the palaeogeographical sense. Pre-existing (possibly Cenozoic) structures in this platform are joints, mainly extensional (fig. 9). According to Hancock (1985) extensional joints in platforms, which incorporate in a deformation belt subsequently may be transformed into shear planes or solution surfaces. Faults can be boundaries between joint domains. In the study area exist both joints, transformed in faults and erosional surfaces. An orthogonal system of joints typical of platforms, (fig. 9a) dominates the substratum. The majority of joints are vertical or steeply inclined, indicating that during failure the effective minimum stress is generally tensile and the stress differences are usually small, as it has been shown by Hancock (1985). Because pre-existing joints can control the nucleation of younger faults, it is possible that neotectonic - active faults of the area follow the pre-existing structure pattern and have been influenced by it (fig. 9b). In this case a simultaneous N-S and E-W (radial) extension could be accepted. It is rather the local stress regime of Yanging area, than its relation with the regional stress pattern that has to be examined.

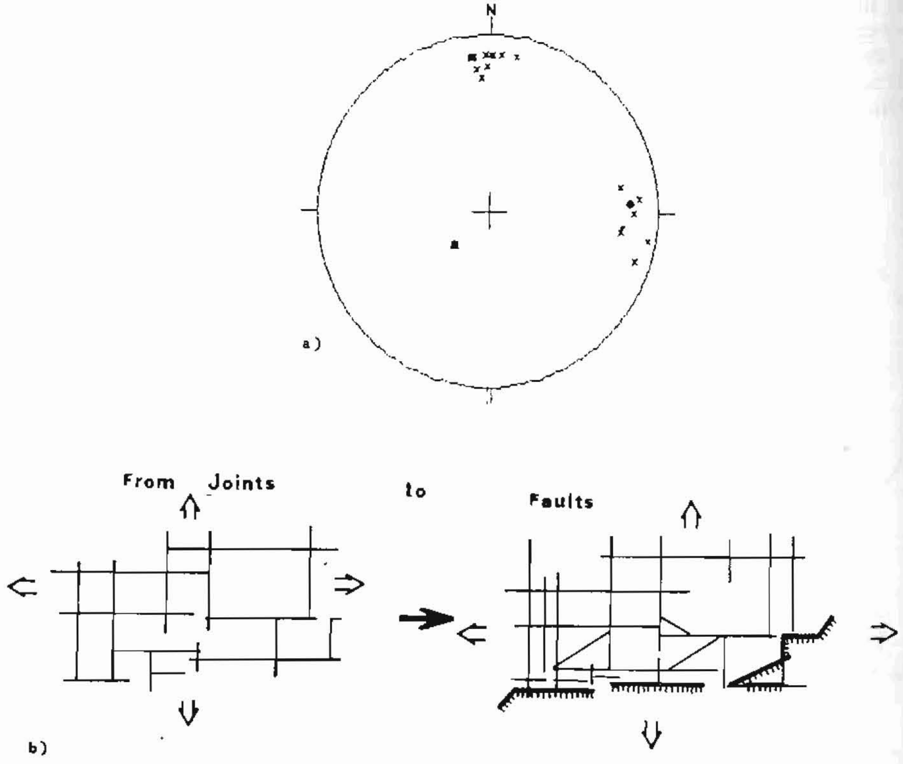

Fig.9. a) A representative set of platform joints as poles (orthogonal fractures affecting dolomites) and the calculated principal stress (strain) axes:

σ_1	227	68	(1%)
σ_2	353	13	(47%)
σ_3	87	17	(52%)

b) Cartoon illustrating the possibly evolution of platform orthogonal joints to shear planes (neotectonic-active faults of the Yianging area).

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