RELATIONSHIP BETWEEN THE MOVEMENT OF ORDOS AND TARIM BLOCKS AND STRONG CONTINENTAL EARTHQUAKES

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ABSTRACT:

On the basis of comprehensive analyses of geology, paleomagnet, GPS data and seismicity, the relationship between the movement of Ordos and Tarim blocks and strong continental earthquakes is discussed. Both Ordos and Tarim blocks are the old intact solid block with simple inner structures, and fault depression zones or orogens around the two blocks are fractural and the inner structures are complex. Whole translational movement to the east and anticlockwise rotation of the Ordos block control the strike-slip fault and earthquake occurrence around the Ordos block, and the movement to the north, clockwise rotation and underthrusting of the Tarim block under orogens result in faulting and earthquake occurrence around the Tarim block. For example, the M≧6 earthquakes in the border of the Tarim block and Tianshan orogens are possibly affected mainly by the motion of the Tarim block although Tianshan is a well-known seismic zone. The traditional stable block like Ordos and Tarim blocks is truly the intact solid active block, which is the main contributor to strong earthquakes on the border. It is difficult for strong earthquakes to occur within tectonic active zones such as fault depression zones and orogens around the integrated solid block because it is not easy for these zones to accumulate big stress due to strong fracture and deformation. It is pointed out that the whole motion of the intact solid block like Ordos and Tarim blocks plays a crucial role in strong earthquake occurrence around its border.

KEYWORDS: Ordos, Tarim, intact solid block, movement feature, strong continental earthquake

1. INTRODUCTION

Ordos and Tairm blocks are two of three stable blocks in China since Mesozoic-Cenozoic. There have been 3 stable blocks in China since Mesozoic-Cenozoic, including Ordos, Tarim and Yangtze blocks (Sun and Zhang, 1999). These stable blocks have some common features, relatively thick lithosphere, crust of about 43-45 km thick and relatively stable lower crust with high density. Generally speaking, there is no seismicity or is only weak seismicity within the stable block.

The earthquakes frequently occurred within the plates over the past decades in the globe, however, make it necessary to study distribution and causes of seismic activity and geodynamics associated with stable regions. Three earthquakes (M=6.0-7.7), causing heavy loss, hit SCR region of India stable continent in 1993-2003(Liu et al, 2004). In 1997-2003, ten M≧6 earthquakes occurred in Jiashi region of the Tarim block that was thought to be stable. The seismic activity has been very strong around the Ordos block. The M=8 Wenchuan earthquake occurred in the western margin of the Yangtze block on May 12, 2008. There are many continental strong earthquakes in the border of other Archaeozoic cratons (stable blocks) such as eastern North American platform and Australia block. We have to consider such a question: What is the relationship between stable block and continental strong earthquake?

This paper studies further characteristics of Ordos and Tarim blocks and their relation with continental strong earthquake (M≧6), and discusses the role of intact solid block, traditional stable block, in the continental strong earthquake on the basis of comprehensive analysis of newest results of geology, paleomagnet, GPS data and seismicity.

2. CHARACTERISTICS OF ORDOS AND TARIM BLOCKS AND EARTHQUAKE

Ordos and Tarim blocks have many same and different characteristics, and the close relationship with strong earthquakes

2.1. Characteristics of the Ordos block and earthquake

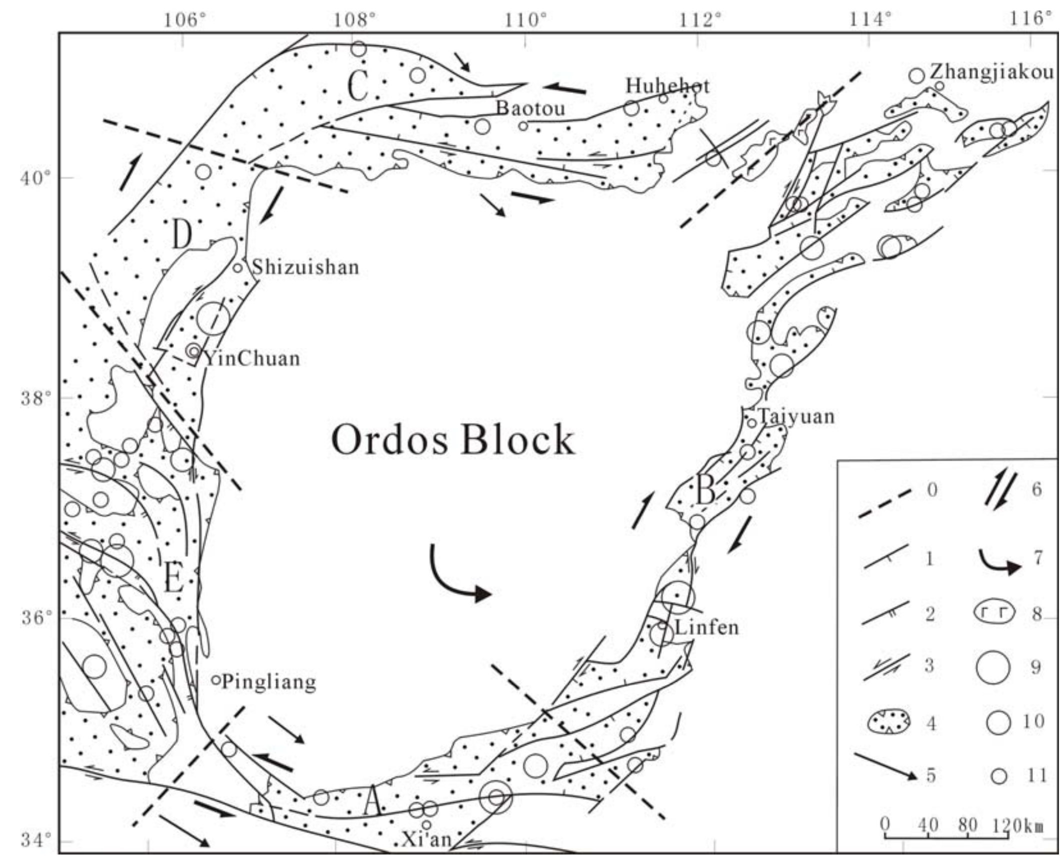

Figure 1 Active tectonics in the Ordos block and its periphery (Modified from reference Deng et al., 1999)
1. Boundary of fault depression zone；2. Normal fault; 3. Thrust; 4. Strike-slip fault; 5. Basin and its boundary; 6. Velocity vector of GPS observation (10mm/a); 7. Relative slip direction between blocks; 8. Direction of block rotation;9. Cenozoic volcanic rock; 10. Ms≧8; 11. Ms=7-7.9; 12. Ms=6-6.9；A. Weihe fault-depression

zone；B. Shanxi fault-depression zone；C. Hetao fault-depression zone；D.Yinchuan-Jilantai fault-depression zone；E. Arcuate tectonic region.

The Ordos block (Figure 1) is an ancient intact solid block with simple inner structures, and there are compressional zone and down-faulted depression zones around the block. The Ordos block located in the west part of North China sub-plate within the Eurasian plate is an intact active block (Ma, 1999; Zhang, 1999; Zhang and Zhang, 2000, 2004) since Mesozoic-Cenozoic, but its basement is Archaeozoic. The compressional zone in the southwestern margin of the Ordos block and other Cenozoic faulted depression zones around the Ordos block are fractural, active tectonic zone with complex inner structures (Liu et al., 2004, 2006, 2008). The faulted depression zones surrounding the Ordos block are shear zone with extensional component. Both the Yinchuan-Jilantai faulted basin zone of its western boundary and the Shanxi faulted basin zone of its eastern boundary are NNE-trending dextral shear zones with extension components, while both the Weihe faulted basin zone of its southern boundary and the Hetao down-faulted basin zone of its northern boundary are nearly EW-trending sinistral shear zones with extensional components (Deng et al., 1999).

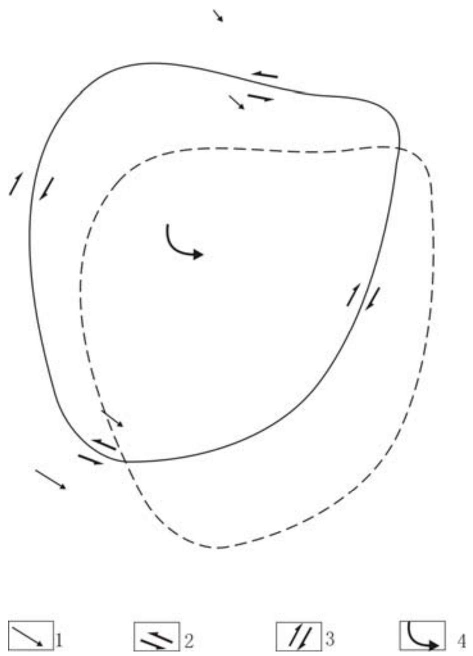

Figure 2 Sketch map showing the movement of Ordos block

1. Velocity vector of GPS observation; 2. Sinistral slip; 3. Dextral slip; 4. Direction of block rotation. (Solid circle shows block boundary and present location and dotted circle shows the future location induced)

The model of whole translational movement to the east and anticlockwise rotation of the Ordos block can make both the dextral shear and the sinistral shear harmonious (Figure 1 and Figure 2). Results of paleomagnet (Xu et al., 1994; Li et al., 2001; Zhang et al., 1998) show that the Ordos block anticlockwise rotates relative to neighboring blocks in the Quaternary. The dextral slip of faults in the eastern and western boundaries of the Ordos block is obviously consistent with the anticlockwise rotation of the block, but the sinistral slip in the northern and southern boundaries of the block seems contrary to the anticlockwise rotation of the block. In fact, if many factors are considered, it is found that both are not contrary to each other. Any horizontal movement of block in the earth's surface can be resolved into translation and rotation around vertical axis. GPS data show that the movement directions of both blocks along fault are the same in the China continent, and that all the strike-slip motion is relative because of different velocity (Li et al., 2003). In the course of eastward movement of eastern part of China continent, speed of southern block is always larger than that of northern block (Wang, et al., 2001; Wang et al., 2003). Therefore, all east-west active faults show feature of dextral strike-slip in the east part of China continent. The speed of eastward movement of South China block is larger than that of the Ordos block, its northern neighbor, so the Qinling north margin fault between both blocks shows the feature of sinistral strike-slip. The speed of eastward movement of the Ordos block is larger than that of Yinshan block, its northern neighbor, so Yinshan piedmont fault between both blocks also shows the feature of sinistral strike-slip. On the basis of comprehensively analyzing the geological tectonics, paleomagnet and GPS data, it may be concluded that the different motion of the Ordos block and the neighboring blocks in the background of the whole eastward movement of east China continent forms EW-trending sinistral strike-slip faults in the northern and southern boundaries of the Ordos block, and that the anticlockwise rotation forms NNE-trending dextral strike-slip in the eastern and western boundaries of the Ordos block.

The whole motion of the Ordos block is associated closely with seismic activities of its peripheral areas. The seismic activities in its peripheral areas are strong, and there are more than 60 $M\geq6$ earthquakes and 4 $M\geq8$ earthquakes. In contrast, earthquakes are few and small within the Ordos block, and the maximum magnitude is 5.5. Data of focal mechanism resolutions in the periphery of the Ordos block show that the focal mechanism of $M\geq6$ earthquakes is mainly strike-slip faulting, that the principal compressional stress axis is near horizontal (Cui et al., 2005), and that the earthquakes are caused by horizontal shear. Focal rupture is consistent with surface active faulting. Focal depth research shows that focal depth in the peripheral areas of the block is the largest in the east China continent (Zhang et al., 2002). The ordos block shows integrated when acting on neighboring blocks (Su, 2000), and its whole motion controls the peripheral strong earthquakes.

2.2. Characteristics of the Tarim block and earthquake

The Tarim block, a part of Xinjiang sup-plate, is located between Tianshan and Kunlunshan orogens (Figure 3). The Tarim block with Archaeozoic basement includes the Tarim basin that is the major part of Tarim block, the Keping uplift, the Quruqtagh uplift, the Altyn Tagh uplift and the Tiekelike uplift. The crustal structure of the Tarim block is simple and its rigidness is larger than that of peripheral orogen.

The Tarim block has been considered to be a stable block and Tianshan orogen in its northern margin is a well-known seismic zone. However, strong earthquakes ($M\geqq6$) in the Tarim block are much more than in Tianshan orogen although $M<6$ earthquakes in Tianshan orogen are much more than in the Tarim block based on all seismic records. Such distribution of strong earthquakes may be unexpected. Jiashi strong earthquake swarm in Xinjiang occurred in the stable Tarim basin, not in Tianshan seismic zone (Zhu et al., 1998). Therefore the relationship between the Tarim block and strong earthquake is worth analyzing.

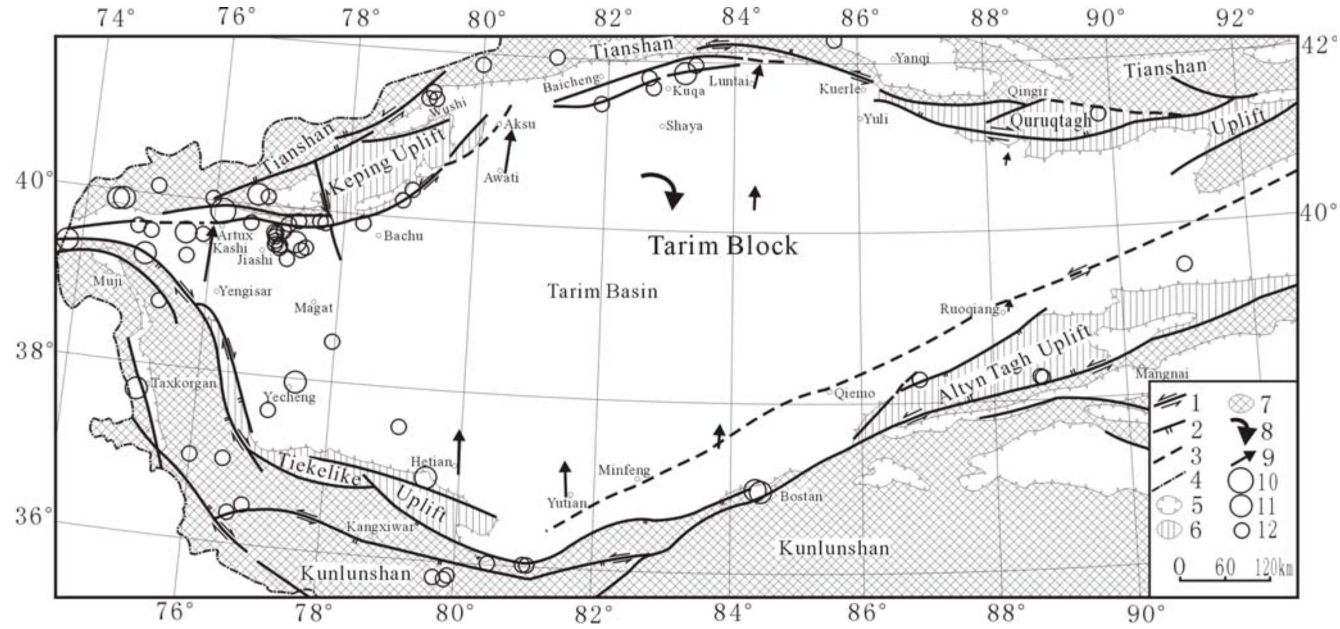

Figure 3 Active tectonics in the Tarim block and its periphery

1.Strike-slip fault；2. Thrust; 3. Buried fault；4. National boundary; 5. Basin and its boundary; 6. Uplift; 7. Orogen; 8. Block and rotation direction; 9. Velocity vector of GPS observation (10mm/a); 10. Ms≧8; 11. Ms=7-7.9; 12. Ms=6-6.9

The Tarim block has not only obvious horizontal movement but also vertical movement relative to peripheral orogen zones. There are strike-slip faults in the boundaries of the Tarim block, for example, NE-trending sinistral strike-slip Altyn Tagh fault in the southeastern boundary. Paleomagnet data show that the Tarim block has clockwise rotated 9º (Chen et al., 1990; Avouac et al., 1993). GPS data (Wang et al., 2003) show that there is velocity difference among different parts of the block when whole Tarim block moves northward. The velocity of northward movement in the western part is larger than in the middle part, and the velocity in the middle part is larger than in the eastern part. Therefore, based on geology, paleomagnet and GPS data, the Tarim block shows horizontally features of clockwise rotation in the course of northward movement (Figure 3). Vertically, it can be seen that Tianshan and Kunlunshan orogens thrust over the Tarim basin in the crustal surface. Deep seismic sounding data show that the Tarim basin is underthrusting under the peripheral orogens(Zhao et al., 2006; Gao et al., 2002; Zhao, 1998). It should be noted that Tarim block is an active block, moving both horizontally and vertically.

The movement of the Tarim block results in strong earthquakes and buried faults within the block control the distribution of strong earthquakes. Focal mechanism resolutions of M≧6 earthquakes are mainly thrusting and strike-slip faulting in the Tarim block and its peripheral areas (Cui et al., 2005), which are consistent with general characteristics of underthrusting under peripheral orogens, northward movement and horizontal clockwise rotation of the block. Although there is no surface seismic rupture zone in Jiashi region of northwestern the Tarim block, Jiashi earthquake swarm occurred in two buried fault zones, one NNE-trending, the other NNW-trending, based on 3D velocity structure inversion from aftershock data (Li et al., 2002).

2.3. comparison of characteristics between Ordos and Tarim blocks

Ordos and Tarim blocks are presently located in North China sub-plate and Xinjiang sub-plate respectively, and their tectonic backgrounds are different. The Ordos block is an uplift region, its periphery is the shear zone with extensional component except for the compressional area in its southwestern margin, there are listric normal faults on the surface of down-fault basins, and the block moves eastward, superposed by horizontal anticlockwise rotation. On the other hand, the main body of the Tarim block is the compressiional basin, its periphery is the orogen where are many thrusts on the surface, clockwise rotation is superposed in the course of northward translation and at the same time the block underthrusts under peripheral orogens.

There are many common characteristics between Ordos and Tarim blocks. Their basements are both very old, there are strike-slip faults in their peripheries, and focal mechanism resolutions are consistent with surface faulting forms. It is another common important characteristic that both blocks are the intact block with high rigidness.

3. DISCUSSION ON RELATIONSHIP BETWEEN INTACT SOLID BLOCK AND STRONG CONTINENTAL EARTHQUAKE

Intact solid block could results in strong earthquake when its movement is obstructed. Intact block can obtain bigger kinetic energy when moving since it is complete in structure. Stress is accumulated where the movement of solid block is obstructed, and a strong earthquake may occur once the stress reaches a critical value to overcome the resistance. The irregular boundary of solid block is the segment easy to accumulate stress and to generate earthquake. Seismogenic model with solid body (Mei, 1995) indicates that strong earthquake source is distributed within the high velocity body, or in the boundary between high and low velocity bodies but close to high velocity body. Research on mechanical model of solid and soft inclusion show solid inclusion (solid body) is an important condition for a lot of strain energy to highly concentrate (Mei, 1995).

The kinetic energy of solid block movement is proportional to intensity of seismicity in the boundary. When the difference of density, thickness and motion rate among blocks is not very large, the area of block could determine the kinetic energy of block and further the intensity of seismicity in the boundary. Ordos is a large solid block so the intensity of seismicity is very large in its periphery where 4 $M \geqq 8$ earthquakes occurred in the history. Qaidam block is a small solid block so the intensity of seismicity is also small.

Present orogen or down-fault zone is the geological unit of active tectonic, and aseismic creeping deformation is an important active form. It is difficult for large earthquake to occur within Orogen or down-faulted basin where the crust is fractural and can not accumulate large stress. There are many $M<6$ earthquakes but few $M \geqq 6$ earthquakes within Tianshan orogen.

4. CONCLUSION

a. Both Ordos and Tarim blocks are the ancient, intact and solid block with simple crustal structures. Down-faulted depression zone and compressional orogen in the periphery of both blocks are fractural with complex inner structures.
b. The whole movement of Ordos and Tarim blocks controls their boundary faulting and peripheral strong earthquakes.
c. Traditional stable block is actually the intact solid active block with large kinetic energy and main contributor to strong earthquakes in the boundary.

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