TECTONIC INVESTIGATION OF EARTHQUAKE REGIONAL ACCUMULATIONS IN AFGHANISTAN

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ABSTRACT

Subsurface and surface studies show that the Afghan region is affected by three main faults and their deformational zones. The right lateral Hari rod fault zone oriented W-E in the middle of Afghanistan and the left lateral Chaman and Badakhsan fault zones oriented NNE-SSW in the eastern boundary of Afghanistan. The seismotectonic maps shows two main accumulation of earthquakes in Afghan region that are different at depth and focal mechanism. one of them located in Hindu Kush area (A region) and another one is located in the Southern part of Transpressional Plate Boundary (B region). The folds have Type 1 and 2 of interference patterns in B.

The A region with the mantel seismicity is clash zone of three plates, where the Arabian and Indian plates subduct beneath the Eurasian plate, and also one of the largest triangular edges of Indian plate boundary is located in the south of this region. Therefore, earthquakes with dip-slip focal mechanism and mantle seismicity at depths occur in A because of stress accumulation. While the B region is located in the boundary between the Arabian and Indian plates that both of them are moves northward with different rate but the Z shape curvature of Indian plate boundary in the B causes to accumulation of stress and occurrence of earthquakes with left lateral strike-slip focal mechanism and crustal seismicity at depths.

INTRODUCTION

Afghanistan is part of the Eurasian plate and its seismicity is driven by the relative northward movements of the Arabian plate past western Afghanistan at 33 mm/yr and of the Indian plate past eastern Afghanistan at 39 mm/yr or faster as both plates subduct under Eurasia (Wheeler et al. 2005). As a seismotectonic map shows geologic, seismological and other information that is pertinent to seismic hazards but previously was scattered among many sources, so Afghanistan seismotectonic map shows active tectonics of the region.

This paper focuses on the regional accumulation of earthquakes on the seismotectonic map of Afghanistan. We sought to identify areas with the highest earthquake concentration and compare them to identify the depth, magnitude and focal mechanism. At last a discussion about tectonic cause of this distribution.

GEOTECTONIC SETTING

Afghanistan is the most stable part of a promontory that projects south from the Eurasian plate (fig. 1; Ambraseys and Bilham, 2003; DeMets et. al., 1990). West of Afghanistan, the Arabian plate subducts northward under Eurasia, and east of Afghanistan the Indian plate does the same. South of Afghanistan, the Arabian and Indian plates adjoin and both subduct northward under the Eurasian promontory. The plate boundaries west, south, and east of Afghanistan are hundreds of kilometres wide. They involve the constructional deformation of large parts of the Eurasian promontory.

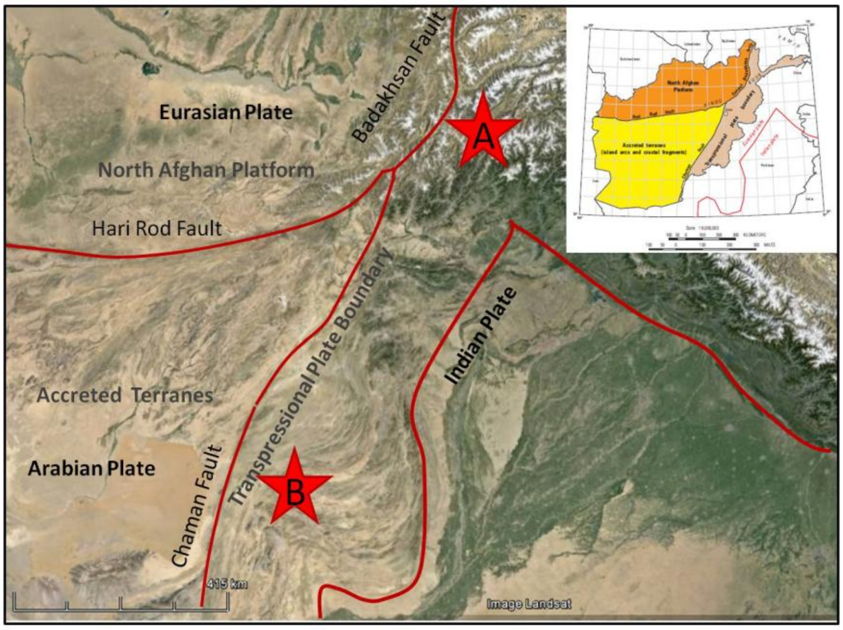

Figure 1. Tectonic map of Afghanistan on satellite image that tectonic regions and main faults are mapped. In the index map: Pink, transpressional plat boundary; yellow, accreted to the platform and orange, North Afghan platform (Wheeler et al., 2005).

More specifically, south of Afghanistan at the Makran subduction zone, the plate contact between the overriding Eurasian plate and the subducting Arabian and Indian plates crops out along a line beneath the Gulf of Oman and the Arabian Sea (fig. 1). Within the plate boundary and north of the plate contact, southwestern Pakistan and southeastern Iran, together with southernmost Afghanistan, make up a broad deformation zone of north-dipping thrust faults and associated folds that trend east (Haghipour et. al, 1984, b; Hessami et. al., 2003). The north-trending direction of plate convergence is nearly perpendicular to the east-trending plate contact (fig. 1). Thus, the deformation zone north of the contact includes dominantly reverse faults and associated folds, with negligible strike-slip faulting (Hessami et. al., 2003).

In contrast, east and west of Afghanistan, the plate boundaries trend north-northeast and north-northwest, respectively. Subduction is oblique, and plate convergence is transpressional. The western plate boundary between Arabia and Eurasia is roughly a mirror image of the eastern boundary between India and Eurasia. The western boundary is entirely within Iran and largely outside the area shown on figure 1; we will not consider the western boundary further. Within the eastern boundary, upper crustal strain of the deformation zone is partitioned into a broad complex of thrust faults at and near the plate contact and a wide, north-northeast-trending belt of left-lateral, strike-slip faults farther inside the Eurasian plate (Haghipour et. al., 1984). The plate contact follows the curved traces of the outermost thrust faults in Pakistan (fig. 1), and the strike-slip belt extends west as far as the left-lateral Chaman fault of Afghanistan (fig. 1). The strike-slip belt contains many large, left-lateral faults that strike north and northeast, and fewer, smaller reverse faults that strike east and northeast and dip northerly (fig. 1; Kazmi and Rana, 1982).

The thrust complexes and strike-slip belts of the deformation zones that form the rim of the Eurasian promontory is all seismically active (Haghipour et. al. 1984; Hessami et. al., 2003). In contrast, the interior of the promontory in western and central Afghanistan is much less active (fig. 2).

METHODS

In this paper, for the recent tectonic analysis of earthquakes distribution, subsurface and surface data analyses are done. Subsurface data is include of the depth and focal mechanism of earthquakes and the surface data is the location of earthquakes and geometry of structures such as fold and faults. For this purpose, trend of the faults and fold axes are mapped in the highest earthquake concentration area then the changes in the magnitude, depth and focal mechanism of the earthquakes are investigated and based on the evidence, the results are presented.

EARTHQUAKES EVIDENCE

Figure 2 shows the map distribution of Afghan and nearby earthquakes within two depth ranges that correspond roughly to mantle (Fig. 2a) and crustal seismicity (Fig. 2b). The greatest concentration of crustal earthquakes is in and around the A and B regions (Fig. 2b). At mantle depths, seismicity is almost exclusively in the A region (Fig. 2a).

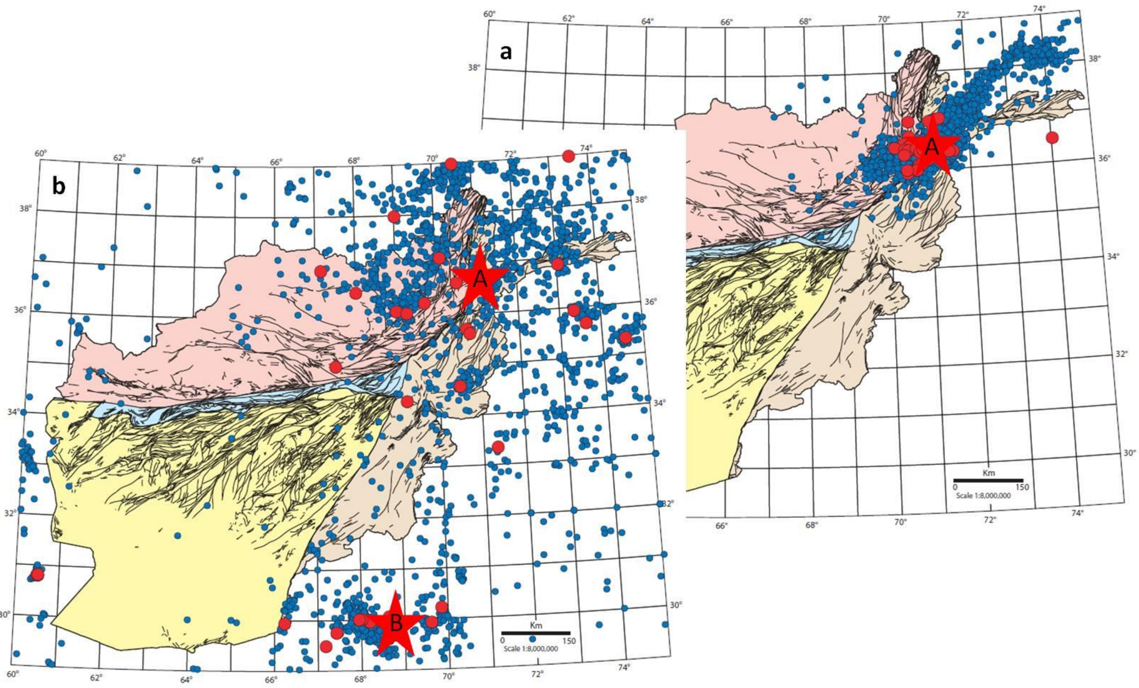

Figure 2. Seismotectonic map of Afghanistan (Wheeler et al., 2005). a. Mantle seismicity at depths greater than 100 km. Blue dots, magnitudes 4.0–5.9; red dots, magnitudes 6.0–7.9; red 5-point star is highest earthquake concentration area. b. Crustal seismicity at depths of 40 km or less. Blue dots, magnitudes 4.0–5.9; red dots, magnitudes 6.0–7.9; red 5-point stars are highest earthquake concentration areas.

In Figure 3, the focal mechanism of earthquakes indicates two different mechanisms that are match with A and B regions. The A dominated by dip-slip mechanism especially reverse and the B dominated by left-lateral strike-slip mechanism.

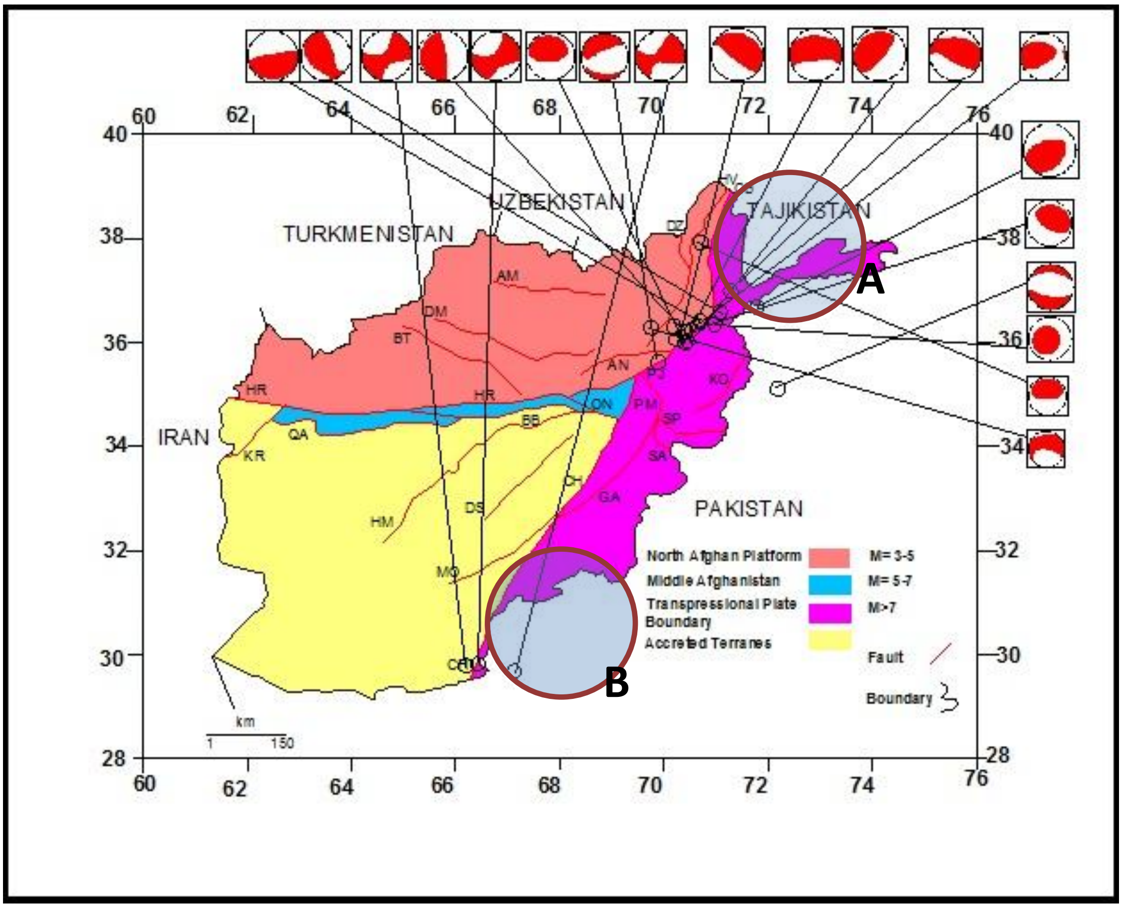

Figure 3. The focal mechanism of some 1976-1980 earthquakes (for example) in the highest earthquake concentration areas (A&B).

STRUCTURES AND ACTIVE FAULTS

Structural geology of Afghanistan shows that the region is affected by three main faults and their deformational zones (Fig. 1). The Hari rod fault zone oriented W-E with right lateral strike-slip movement in the middle of Afghanistan. The Hari Rod fault has a striking geomorphic expression on the satellite images (Fig. 1). There is evidence for and against its present-day activity. Sborshchikov et. al., (1981) examined satellite images and noted 800 m of right-lateral offsets of streams along Hari Rud river. On the other hand, there is no earthquake along the fault on the Figure 2.

The Chaman fault has the most evidence for seismic activity than the Hari Rud (Fig. 2). It is part of the western edge of the transpressional plate boundary between Eurasia and India (Fig. 1). Movement of the fault has produced surface ruptures along the fault trace that can be seen on the satellite images. There is 60 km of surface rupture with several meters of vertical offset (Quittmeyer and Jacob, 1979). Based on the seismotectonic maps (Fig. 2) the Chaman fault is an active fault but it less active than the Badakhsan fault zone that oriented NNE-SSW with left lateral strike-slip movement in the north of the Chaman fault (Fig. 1).

Structural geology study of the A and B regions (Fig. 2) shows that these regions have specific structural features. For example the structures of the B and surrounding area are mapped on the satellite image (Fig. 4a). In this area the collision between Indian and Arabian plats cause to formation of simply fold-trust belt (Fig. 1). The axial traces of folds are significant on the satellite images (Fig. 4a). As can be seen the boundary of the plats is curved (blue line in Fig. 4a). In the east and west, the axial traces of the folds are parallel to the collision boundary, E-W trending in the east and N-S trending in the west with lesser curvature, (Fig. 4a). But in the B, where the boundary has main curved feature, the geometry of the folds are different (Fig. 4b). Interference of E-W and N-S trending of the fold axes in the B, results in formation of Type 1 and 2 of interference patterns which are clearly visible in the satellite images (Fig. 4b) and Suggests that stress accumulations in this place are release as earthquake.

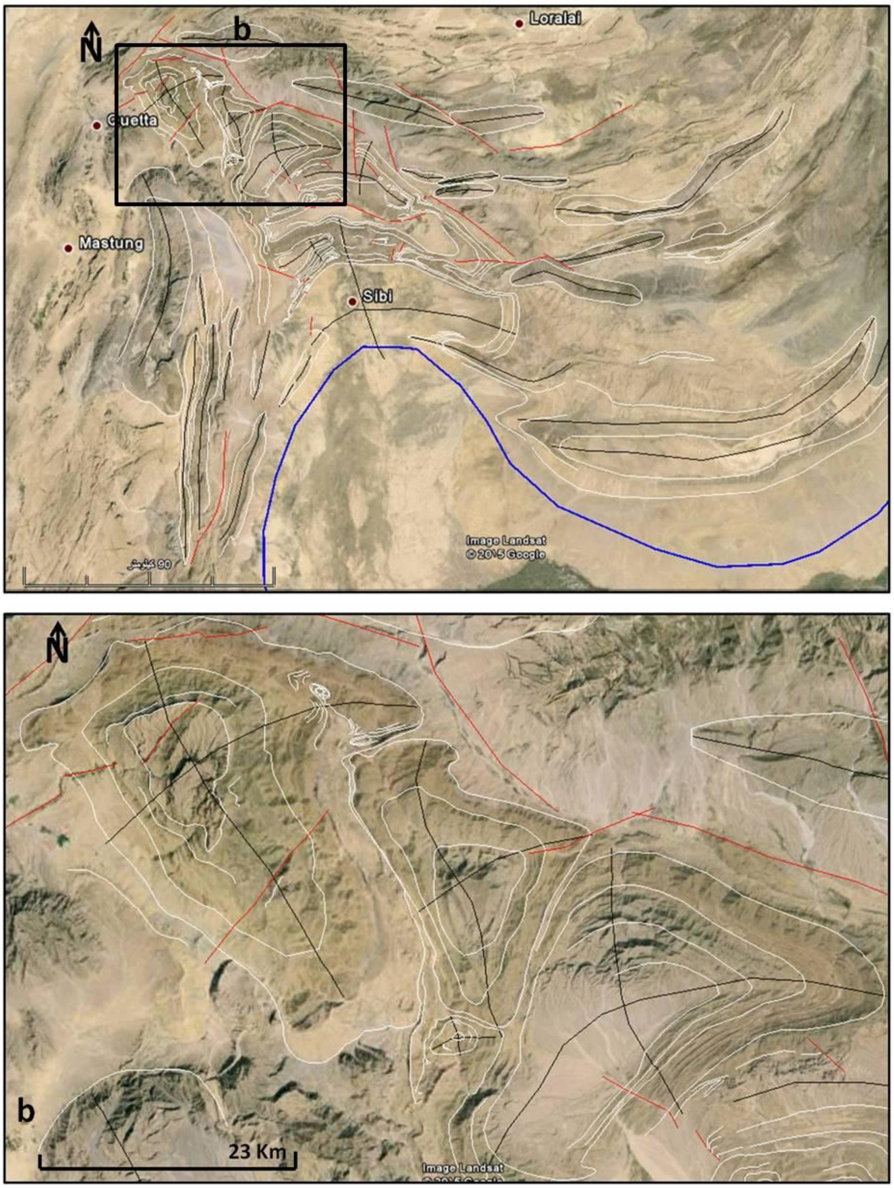

Figure 4. a. Structural map of the B region (marked on the Fig. 2b) and the surrounding areas on the satellite image. b. Detailed structural map of the B region. Blue line, the boundary of the plates; red line, trace of the faults; white line, trace of the bedding; black line, fold axial trace.

DISCUSSION AND CONCLUSIONS

Davoodi (2013) and this article are believed that the seismotectonic map of Afghanistan shows two main accumulation of earthquakes in Afghan region (Fig. 2), one of them located in Hindu Kush area, where the triangular edge of Indian plate is collision with Eurasia plate (A in the Figures 1 and 2), another one is located in the Southern part of Transpressional Plate Boundary, where the Indian plate boundary shows Z shaped curvature (B in the Figures 1 and 2). Distribution of the earthquakes indicates that the A region is wider than B. Due to the previous studies (Wheeler et al., 2005) (Fig. 2), the crustal earthquakes are located in the both regions whiles the mantle earthquakes are locate in the A region.

The focal mechanism of earthquakes indicates two different mechanisms that are match with A and B regions. The A dominated by dip-slip mechanism especially reverse and the B dominated by left-lateral strike-slip mechanism (Fig. 3).

The A region is clash zone of three plates, where the Arabian and Indian plates subduct beneath the Eurasian plate, and also one of the largest triangular edges of Indian plate boundary is located in the south of this region. Therefore, the A region is a place for accumulation of stress due to the subduction, so earthquakes with dip-slip focal mechanism and mantle seismicity at depths occurs. While the B region is located in the boundary between the Arabian and Indian plates that both of them are moves northward with different rate. Arabia moves with respect to a fixed Eurasia at 33mm/yr, and India dose the same at 39 mm/yr (Wheeler et al., 2005). The Z shape curvature of Indian plate boundary in the B region causes to accumulation of stress, so earthquakes with strike-slip focal mechanism and crustal seismicity at depths occurs.

REFERENCES

Ambraseys N and Bilham R (2003) Earthquakes in Afghanistan, Seismological Research Letters, v. 74, no. 2, p. 107–123

Davoodi Z (2013) Distribution of the recent deformations of Afghanistan region along the Chaman active fault zone, International Van earthquake symposium, 23-27 October, Van, Turkey

DeMets C, Gordon RG, Argus DF and Stein S (1990) Current plate motions, Geophysical Journal International, v. 101, p. 425–478

Haghipour A, Ghorashi M and Kadjar MH (1984) Seismotectonic map of Iran, Afghanistan and Pakistan: Commission for the Geological Map of the World, United Nations Educational, Scientific and Cultural Organization and Geological Survey of Iran, scale 1:5,000,000

Hessami K, Jamali F and Tabassi H (2003) Major active faults of Iran: Tehran, Iran, International Institute of Earthquake Engineering and Seismology, scale 1:2,500,000

Kazmi AH and Rana RA (1982) Tectonic map of Pakistan, Geological Survey of Pakistan, scale 1:2,000,000

Quittmeyer RC, Farah A and Jacob KH (1979) The seismicity of Pakistan and its relation to surface faults, Geological Survey of Pakistan, p. 271–284

Sborshchikov IM, Savostin LA and Zonenshayn LP (1981) Present plate tectonics between Turkey and Tibet, Tectonophysics, v. 79, no. 1-2, p. 45–73

Wheeler RL, Bufe CG, Johnson ML and Dart RL (2005) Seismotectonic map of Afghanistan, with annotated bibliography, USGS open file report, 011: 1-31