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Tectonic Forecast of Strong Earthquake Sources in Western Tien Shan Microplate

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ABSTRACT

Fault-fold-block structures of the Earth's crust play a critical role in the formation of stress states and in controlling seismic processes. These structures, along with the faults that border them, accumulate stresses and are responsible for generating strong earthquakes. A detailed analysis of geological, geophysical, and seismic data, combined with mathematical modeling has allowed the identification of fault structures and blocks of higher ranks. Investigating the stress state of such structures and the patterns of their interaction is allowed essential for predicting the sources of strong earthquakes. This study examines the seism tectonics of similar structures in the Uzbek segment of the Western Tien Shan microplate.

KEYWORDS

Tectonics; Earth's crust; Mathematical model; Stress; Geodynamics; Western Tien Shan

ARTICLE HISTORY

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Introduction

The classical method for studying tectonic stresses is the analysis of earthquake source mechanisms. Issues related to the stress state of the Earth's crust in Central Asia, and particularly in the Western Tien Shan microplate, have been previously addressed in several fundamental works [1,2]. Studies based on geological and geophysical data and reconstructions of earthquake mechanisms have provided valuable results for stress state assessments [3-6]. Global data on tectonic stresses across continents and regions have been summarized in works [7-9]. Some works have identified relationships between deformation features and stress states in the Western Tien Shan microplate [10-12]. However, these studies have often been limited to reconstructing regional geodynamic stress types only. Determining the stress magnitudes themselves remains important for predicting potential earthquake sites. An attempt to determine the stress state in the seismically active layer of the Central Asian crust by mathematical modeling was made in [13]. Refining the geological boundaries of fold-thrust-block structures (FFBS) and their detailed zoning will help identify such sites. The main processes forming FFBS of various ranks underlie modern movements. Modern crustal movements are characterized by spatial order and inheritance, which, in the geological conditions of the Western Tien Shan microplate, are closely related to neotectonics structures of various ranks. Models of the stress-strain state of FFBS must be based on quantitative data on modern movements, including.

1. Instrumental and space geodetic observations,
2. Seismic regime parameters,
3. Data on fracturing and other geodynamic processes.

Seism active faults play the role of boundaries, along which are often located:

- Epicenters of strong earthquakes,
- Clusters of weak earthquakes,
- Exodynamic phenomena (seismodislocations, fissures, clastic dikes, etc.).

Based on the lithospheric plate hypothesis, many specialists have identified the boundaries of plates and microplates. One of the earliest works on the region's geodynamics, aligning with modern concepts of lithospheric plate tectonics, is the work of E. Argan [14]. Significant contributions to the study of recent tectonics in Central Asia were made by S. S. Shultz, who systematized geological mapping data from the early 20th century and established patterns in the development of neotectonics structures in the region [15]. These patterns were further developed in works [16-20]. Instrumental geodetic and space geodetic data have made significant contributions to studies of modern movements and deformations, reflecting heterogeneities in the structure of the Earth's crust and the distribution of stresses. The goal of our study is to develop a geodynamic model of the Western Tien Shan microplate, zone FFBS of the second and third ranks, and analyze their interactions, which determine the stress state of the seismically active layer.

Materials and Methods

The Ferghana Basin and its mountainous surroundings located in the Eastern Tian Shan microplate (indicated by number 1 in Figure 1) are considered key objects of analysis due to their high seismic activity within Uzbekistan and their genetic connection to adjacent tectonic blocks. For the purposes of further seism geodynamic analysis, the territory of the Western Tien Shan microplate is conventionally considered as a first-order structure. It is bounded (Figure 2) on three sides by first-order active faults:

- Aksu-Maidantal-Bogonal Fault (northwest),
- Talas-Ferghana Fault (northeast),
- Gissar-Kokshal Fault (south).

Modern structures in the region were formed as a result of intracontinental collisional mountain-building, caused by interactions among the Eurasian, Indian, and Arabian plates. The lateral heterogeneity of the crust reacts differently to the

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pressures of the Indian and Arabian plates. Internal basins, formed between blocks, experience bilateral compression. The mountain systems of the Tien Shan and the adjacent Scythian-Turan Plate are considered a unified seismogeodynamic system that determines the features of seismicity in this territory [20]. Evidence includes the distribution of earthquake foci:

- Most are confined to the upper crust (not deeper than 30–35 km),
- Deep-focus earthquakes are observed only along deep faults that disrupt lithospheric continuity.

The latest epiplatform orogenesis in Central Asia reflects the influence of two main factors: stress during horizontal compression and the decompression of subcrustal mantle layers. The northward movement of the Indian plate since the Oligocene has dictated the collision of structures within the Alpine-Himalayan fold belt. The transmission of stress into the depths of Asia has resulted in the emergence of a complex system of mountain ranges and basins, not only in Central Asia but also far beyond its borders. The geodynamic scheme of the Central Asian section of the Alpine-Himalayan mountain belt, based on a comprehensive set of geological and geophysical data and geodynamic models from various authors, is presented in Figure 1. The figure also depicts the external boundaries of the Western Tien Shan microplate and the movement directions of adjacent microplates and blocks.

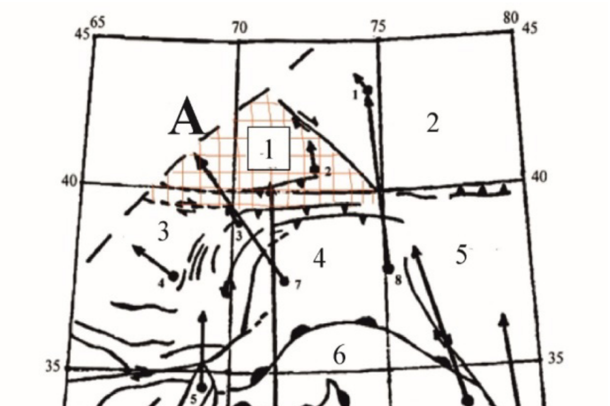

Figure 1. Geodynamic scheme of the Central Asian section of the Alpine-Himalayan mountain belt. - Research area: Ferghana basin, Uzbekistan. Plates in the diagram: A-Eurasian Plate, B- Indian Plate. Microplates: 1-Western Tien Shan, 2- Central Tien Shan, 3- Afghan-Tajik, 4- Pamir, 5- Tarim, 6-Himalayan. - thrust faults, - reverse faults - strike-slip faults, - GPS movement directions., - GPS measurement points

To quantitatively assess the amplitudes of neotectonic movements, a map of neotectonic movement amplitudes was created. Its foundation includes:

- The map of recent tectonic movements of the USSR [21]
- The map of recent tectonics of Asia [22-24]
- The geological atlas of Uzbekistan [25]
- The map of neotectonics of Uzbekistan [26]
- Mechanisms of earthquake foci and residual deformations from strong earthquakes.

The second-order fold-thrust-block structures of the Earth's crust within Western Tien Shan microplate are reconstructed [27] (Figure 2):

- Chatkal-Kuramin (A),
- Pre-Tashkent(B),
- Ferghana(C),
- Atoynok-Ferghana(D),
- South Ferghana(E).

Which bounded by North Ferghana, South Ferghana, East Ferghana faults and Pre-Tashkent flexural zone.

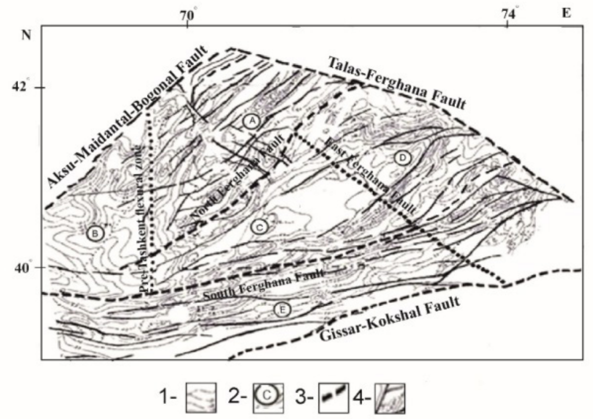

Figure 2. Contour lines of neotectonic movement amplitudes of the Western Tien Shan microplate and second-order fold-thrust-block structures. 1- Amplitude of neotectonic movements, 2- Second-order structures, identified based on amplitude characteristics and a combination of geological and geophysical data: A – Chatkal-Kuramin, B – Pre-Tashkent, C – Ferghana, D – Atoynok-Ferghana, E – Southern Tien Shan; 3- Boundaries of second-order neotectonic structures, represented as: a – active faults, b – morphologically defined boundaries or those determined by movement amplitudes. 4- Internal active faults (within the structures).

It is well known that the Earth's crust consists of hierarchically arranged blocks of various ranks [28]. The boundaries of these blocks are zones of weakness that manifest under strong exogenous influences. According to M. A. Sadovsky, smaller discontinuities merge to form faults. A system of faults develops into deep faults, which, in turn, evolve into lineaments. In the Tien Shan, the linear size of these blocks' averages about 50 kilometers [29]. Consequently, the question of dividing second-order blocks into higher-rank blocks arose.

Preliminary refinements were made to identify active faults which were classified based on:

- Morphology,
- Genesis,
- Amplitude of displacements,
- Seismic activity (including paleoseismodislocations),
- Geophysical and hydrogeological characteristics.

As a result of data collected from various sources, the following system of active faults was identified:

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1. Northwestern System
   - Talas-Ferghana Fault,
   - Kumbel-Kokand-Haydarkan Fault – a normal-slip and strike-slip zone with significant lateral displacements.
2. Northeastern System
   - North Ferghana Fault,
   - Aksu-Maidantal and Bogonalin Faults.
3. Sub-latitudinal System
   - Gissar-Kokshal Fault.
4. Flexure-fracture zones:
   - Pre-Tashkent
   - North Ferghana
   - South Ferghana
   - East Ferghana

An additional impetus for dividing second-order blocks into third-order blocks came from the results of mathematical modeling of the stress state of the Western Tien Shan microplate. Modeling of modern movement adapted for estimating the stress state of the Earth's crust in the average the study area within Talas-Ferghana, Aksu-Maidantal-Bogonal and Gissar-Kokshal was performed using Stokes equations [30,31]:

$$-grad\,\overline{p} + \mu\Delta\overline{v} = \overline{F} \tag{1}$$

$$F_1 = -\overline{\frac{\partial M_2}{\partial x_3}} - \frac{1}{(h-H)}\frac{\partial H}{\partial x_1}\overline{\sigma_{11}} - \frac{1}{(h-H)}\frac{\partial H}{\partial x_2}\overline{\sigma_{12}} - \frac{\mu}{(h-H)}\left(\frac{\partial H}{\partial x_1} + \frac{1}{2}\frac{\partial H}{\partial x_2}\right)\overline{v_1} - \frac{\mu}{2(h-H)}\frac{\partial H}{\partial x_1}\overline{v_2} - -\frac{k_a \rho g(h-H)}{2\mu / t_0} \tag{2}$$

$$F_2 = -\overline{\frac{\partial M_3}{\partial_1}} + \overline{\frac{\partial M_1}{\partial x_3}} - \frac{1}{(h-H)}\frac{\partial H}{\partial x_1}\overline{\sigma_{12}} - \frac{1}{(h-H)}\frac{\partial H}{\partial x_2}\overline{\sigma_{22}} - \frac{\mu}{2(h-H)}\frac{\partial H}{\partial x_2}\overline{v_1} - \frac{\mu}{(h-H)}\left(\frac{1}{2}\frac{\partial H}{\partial x_1} + \frac{\partial H}{\partial x_2}\right)\overline{v_2} - \frac{k_a \rho g(h-H)}{2\mu / t_0} \tag{3}$$

In these formulas, H (x_1,x_2) is the topography of the Earth's surface, $h(x_1,x_2)$ is the Moho depth, ρ is density and μ is the viscosity coefficient. In these equations, stresses are related to the average shear modulus μ, the coefficient a linear variable to h. In the calculations for different blocks, the shear modulus μ is chosen differently. $\bar{p}$ is avareged pressure, $\bar{v}$ is two-dimensional vector with components of averaged horizontal displacement velocities, Δ- two-dimensional Laplace operator, k_a is the coefficient of friction at the Moho boundary. The time scale t_0 is consistent with the fact that the maximum relaxation time of rock stresses is measured by a segment of no more than 10^4 years. In the derivation of the equations, the relations resulting from the rule of the adopted averaging are also used:

$$\overline{\sigma}_{33} = \frac{1}{2}(\sigma_{33}|_h + \sigma_{33}|_H) = \frac{1}{2}\sigma_{33}|_h = \frac{1}{2}\frac{\rho g(h-H)}{\mu / t_0} \tag{4}$$

$$\overline{\sigma}_{i3} = \frac{1}{2}(\sigma_{i3}|_h + \sigma_{i3}|_H) = \frac{1}{2}k_a\frac{\rho g(h-H)}{\mu / t_0} \tag{5}$$

for i=1,2.

The averaged incompressibility equation assuming $v_3(x_1, x_2, h)=0$ takes the form:

$$v_3(x_1, x_2, H) = (h-H)\left(\frac{\partial\overline{v}_1}{\partial x_1} + \frac{\partial\overline{v}_2}{\partial x_2}\right) - \frac{\partial(h-H)}{\partial x_1}\overline{v}_1 - \frac{\partial(h-H)}{\partial x_2}\overline{v}_2 \tag{6}$$

The boundary conditions with respect to velocities are adopted according to GPS data conducted by the staff of the Institute of Seismology of the Academy of Sciences of Uzbekistan. The equations (1-6) were solved by the method of boundary integral equations described in [13].

Results and Discussions

Verification of the solution of equations (1-6) with existing ground-based instrumental and space geodetic observations, as well as seismicity data, enabled the division of the study area into several zones differing in the directions of horizontal displacement velocities (Figure 3).

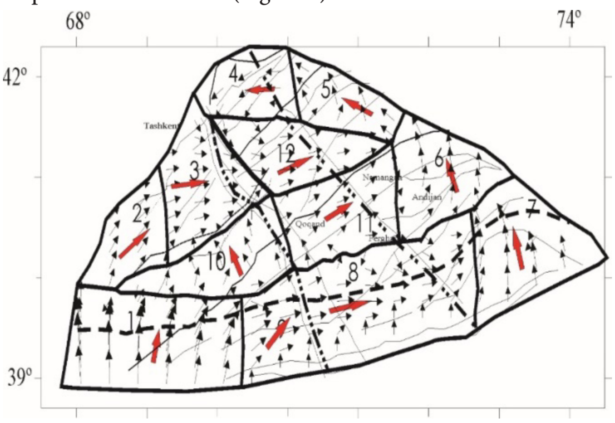

Figure 3. Crustal blocks of the Western Tien Shan identified by directions of horizontal displacement velocities based on mathematical modeling.

Comparison of the boundaries of these zones with active faults, combined with amplitude characteristics of neotectonic movements and other geological, geophysical, and seismological data, allowed for the division of second-order FFBS into higher-rank blocks. Below is a list of the higher-rank blocks (Figure 4).

Chatkal-Kuramin fault-folded-block structure (FFBS) of the 2nd rank (A) (Fig. 2) is bounded on two sides by active faults. To the northeast, it is bordered by the Talas-Fergana fault, and to the northwest, by the Aksu-Maidantal- Boganalinsky faults of the 1st rank. The remaining boundaries are formed by active faults of the 2nd rank: to the southeast by the North Fergana fault and to the west by the Pre-Chatkal-Kuramin flexural-shear zones.

Based on several indicators (deep structure, amplitude characteristics, etc.), the Chatkal-Kuramin FFBS of the 2nd rank (A) is divided by the Kumbel-Kokand-Haydarkan active fault into northern (A_1) and southern (A_2) parts.

The boundary of the North Chatkal-Kuramin FFBS of the 3rd rank (A_1) is formed by the same active faults that delimit the Chatkal-Kuramin block of the 2nd rank (Fig. 2), while its southern boundary is controlled by the Kumbel-Kokand-Haydarkan active fault.

The boundary of the South Chatkal-Kuramin FFBS of the 3rd rank (A_2) is defined by the same active faults that delimit the Chatkal-Kuramin fault-folded-block structures of the 2nd rank. To the west, it is bordered by the Pre-Chatkal-Kuramin flexural-shear zone. This area includes the Karzhantau and Kuramin FFBS of the 4th rank.

The Paleozoic basement in the FFBS of the 3rd rank rises to elevations of 4500m and 3700m, respectively, and in the separating troughs, the basement does not sink below elevations of 2000m and 1500m. The aforementioned FFBS of the 4th rank

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dips southwestward, submerging beneath the Mesozoic and Cenozoic deposits of the adjacent Pre-Tashkent fault-folded-block structures.

The Pre-Tashkent fault-folded-block structure (FFBS) (B) is connected to the Chatkal-Kuramin FFBS of the 2nd rank (A_1) via the Pre-Chatkal-Kuramin flexural-shear zone (FSZ). The transition toward the Turan platform of the Eurasian lithospheric plate is gradual and features an asymmetrical structure. Its axis stretches from northeast to southwest. According to geophysical data, the basement depth in this area reaches 3000m.

Almost all positive and negative FFBS structures of the 4th rank identified within the Pre-Tashkent FFBS (B) are direct continuations of the South Chatkal-Kuramin FFBS of the 3rd rank (A_2). These structures have northeastward orientations and are buried beneath a thick sequence of Mesozoic and Cenozoic deposits.

The Fergana FFBS of the 2nd rank (C) has divided into several parts. Instrumental observations have shown that Andijan and its surroundings are subsiding at a rate of 10 mm per year. In the same area, sections with both compressing and stretching modern cracks have been identified, located in the zone of dynamic influence of the Southern Fergana flexural fault zone. These facts may indicate that the eastern part of the FFBS is simultaneously subjected to sub-vertical and northeast-directed extension. In this case, the Fergana FFBS is considered as a subsidence structure against the background of tangential compression of the surrounding mountain structures.

The internal structure of the Fergana FFBS of the 2nd rank is closely related to the Atoynok-Fergana FFBS of the 2nd rank. The central graben is bordered on both sides by the Northern Fergana and Southern Fergana FFBS of the 3rd rank (C_1 and C_4). According to Peshkova, the central graben is divided into two 3rd-rank FFBS: Western Fergana (C_2) and Eastern Fergana (C_3) [32]. Separated by the Kumbel-Kokand-Haydarkan fault, the Western Fergana convergent FFBS (C_2) has undergone recent compression due to opposing bilateral overthrusting of the Chatkal-Kuramin and South Tien Shan FFBS of the 2nd rank, while the Eastern Fergana monovergent FFBS (C_3) responded to overall compression with a unilateral northward thrusting of its structures.

It has been noted that the Eastern Fergana FFBS of the 3rd rank (C_3) is subjected to simultaneous sub-vertical and northeast-directed extension.

The Atoynok-Fergana FFBS of the 2nd rank (D) borders the Fergana FFBS from the northeast. These are complexly structured asymmetric uplifts; whose northeastern part adjoins the Talas-Fergana fault. The southwestern part of the FFBS branches out in the form of virgations and continues beneath the Mesozoic-Cenozoic cover of the Fergana FFBS.

The natural boundaries of the Atoynok-Fergana FFBS are the Talas-Fergana fault from the northeast and the Eastern Fergana fault from the southwest. This structure, based on several indicators (contour map patterns, amplitude characteristics, and topography), is divided into the North Fergana (D_1) and South Fergana (D_2) flexural fault zones, and the 3rd-rank FFBS(D3).

The South Tien Shan FFBS of the 2nd rank (E) has a neotectonic structural plan complicated by zones of transverse disruptions with meridional and northwest orientations. These zones are often associated with areas of fracturing, imbricate structural junctions, and accompanying horizontal displacements. Considering these transverse faults, contour map patterns, topography, and amplitude characteristics, the South Tien Shan FFBS is divided into the following 3rd-rank structures: E_1, E_2, and E_3 (see Figure 4).

These blocks share a similar neotectonic history, comparable amplitudes of recent movements, and orientations of 4th-rank structures. Among the fault-fold-block structures of the 4th rank, the Turkestan, Alay, Zeravshan, and Hissar structures with sublatitudinal orientations are distinguished.

The Turkestan and Alay FFBS have steeper northern and gentler southern wings, with elevations reaching up to 5500 meters. To the north, these blocks are bordered by the Southern Fergana deep fault. Along this fault, on the side of the Fergana depression, are located the 5th-rank FFBS: Malguzar, Uratyube, and Sulyukta-Takhtabuz structures.

The Zeravshan FFBS has a latitudinal orientation, with Paleozoic deposits raised to elevations of 4500–5000 meters. The steeper northern wing is bordered by the Zeravshan section of the Karatau-Zeravshan fault. Within it, the Chimtarg fault-fold-block structure stands out sharply, with elevation markers exceeding 5000 meters. This uplift is complicated by faults of northwest, northeast, and latitudinal orientations, which align with the submeridional compression position.
Overall, the southern border zones of this structure represent

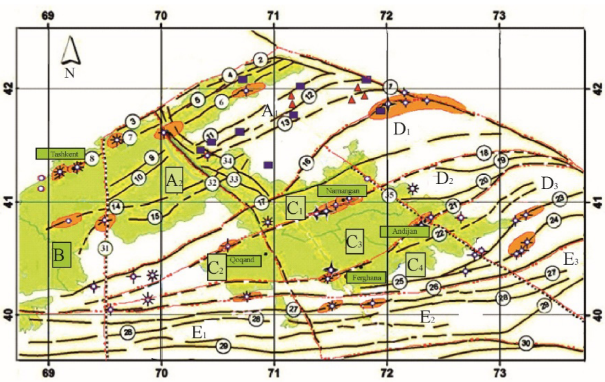

Figure 4. Highlighted 3rd-rank fault-block structures, active faults, macroseismic epicenters of strong earthquakes, and paleoseismodislocations: Active faults of the Earth's crust; Flexural-rupture zones(FRZ); - Fault-fold-block structures of the 3rd rank; - Earthquake epicenters and ; 5 – intensity of earthquakes(in points): ; 6- Paleoseismodislocations: -Researched; - Identified using satellite imagery. Active faults:1- Talas-Fergana; 2- Aksu-Maidantal; 3- Bogonali; 4- North Ugam; 5- Ugam-Maidantal; 6- Pskem; 7- Karzhantau; 8- Pre-Tashkent Flexural-Rupture Zone; 9- Syuren-Atinsky; 10- Sukok; 11- South Pskem; 12- Sandalash; 13- Chatkal; 14 - North Angren; 15- South Angren; 16- Chatkal-Atoynok; 17- North Fergana; 18- North Fergana FRZ; 19- Baubashain; 20- Kuchkarota; 21- South Fergana FRZ; 22- Kugart; 23- Taldysu; 24- Kurshab; 25- Karachatyr; 26- South Fergana; 27- Nuratau-Katran; 28- Karatau-Zeravshan; 29 - Main Gissar; 30 - Gissar-Kokshaal; 31- Pre-Chatkal-Kuramin; 32- Kumbel-Kokand-Haydarkan; 33- Kenkol; 34- Arashan; 35- East Fergana FRZ

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the contact zone between the South Tien Shan FFBS of the 2nd rank and the Pamir tectonic arc.

The highlighted blocks and their boundaries are correlated with the epicenters of strong earthquakes. Figure 5 presents the

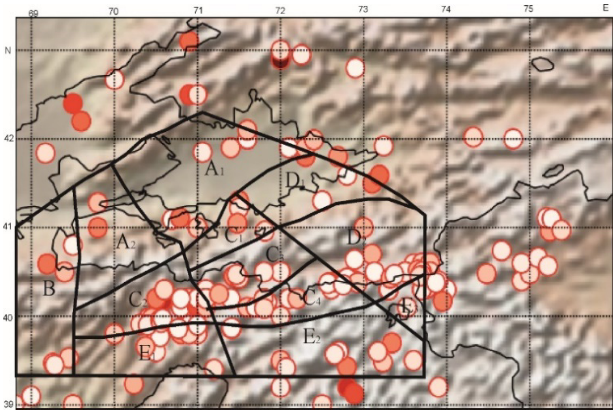

Figure 5. Earthquake foci with magnitudes M≥5: The intensity of the circle's shading corresponds to an increase in magnitude.

earthquake foci with magnitudes M≥5, which have occurred since historical times in the studied and adjacent territories.

The strongest earthquakes occur at the boundaries of the identified blocks, corresponding to active faults. Less intense earthquakes are found at the boundaries of blocks associated with higher-rank faults. This observation aligns with the thesis that the Earth's crust consists of hierarchically arranged blocks. The boundaries of these blocks are zones of weakness, which manifest under strong exogenous impacts. The higher the hierarchy, the smaller the block size, and within these smaller blocks, lower-intensity earthquakes occur.

The analysis of earthquakes allows the identification of the following categories of focal zones:

1st Category: Earthquakes with M≤7.0 (9 points intensity) (symbol ✦ in Figure 4):

- Chatkal, Namangan, Andijan, Fergana focal zones.

2nd Category: Earthquakes with M≤6.0 (8 points intensity) (symbol ✳):

- Pre-Tashkent, Karzhantau, Sandalash, Talas, Chust-Pap, Kayrakkum, Sulyukta, Shurab, Katrantau zones.

3rd Category: Earthquakes with M≤5 (7 points intensity) (symbol ✧)

Focal zones of the 1st category (M≤7) are located:

- Within the Atoynok-Fergana and Fergana FFBS of the 2nd rank.
- In the Fergana FFBS region, which is the most stressed area developing as a rift system.

Focal zones of the 2nd and 3rd categories:

- Located in marginal fault zones and flexural fault zones.
- Found in areas associated with active faults of northeast orientation.

Conclusions

Based on a comprehensive analysis of data on the deep structure, dynamics of tectonic movements and using solutions of mathematical problem of the stress state of the earth's crust the West Tien Shan microplate divided into 2nd- and 3d rank tectonic blocks. The boundaries of the identified tectonic blocks correlate with earthquake foci.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

1. Gzovsky MV. Fundamentals of Tectonophysics; 1975. 536p.
2. Ulomov VI. Dynamics of the Earth's Crust in Central Asia and Earthquake Prediction. Tashkent: Fan; 1974.
3. Osokina DN, Gushchenko OI, Lykov VI, Tsvetkova NYu. Modeling of Local Tectonic Stress Fields Caused by Deep Fault Systems. In: Stress and Deformation Fields in the Lithosphere. Moscow: Nauka, 1979. 185-203p. Available at: https://www.geokniga.org/books/26964#:-:
4. Balakina LM, Vvedenskaya AV, Golubeva NV, Misharina LA, Shirokova EI. Elastic stress field of the Earth and earthquake focal mechanisms; 1972.
5. Sherman SI, Dneprovsky YI. Stress fields of the Earth's crust and geological structural methods of their study; 1989.
6. Rebetsky YL, Ibragimova TL, Ibragimov RS, Mirzaev MA. Stress state of Uzbekistan's seismically active areas. Seismic Instruments. 2020;56:679-700. https://doi.org/10.3103/S0747923920060079
7. Zoback ML. First-and second-order patterns of stress in the lithosphere: The World Stress Map Project. J Geophys Res Solid Earth. 1992;97(B8):11703-11728. https://doi.org/10.1029/92JB00132
8. Zoback ML, Zoback M, Watts A, Schubert G. Lithosphere stress and deformation. Tr Geophys. 2007:253-273.
9. Heidbach O, Rajabi M, Cui X, Fuchs K, Müller B, Reinecker J, et al. The World Stress Map database release 2016: Crustal stress pattern across scales. Tectonophysics. 2018;744:484-498. https://doi.org/10.1016/j.tecto.2018.07.007
10. Shirokova EI. Detailed Study of Stresses and Fractures in Earthquake Foci in Central Asia. Izvestiya An Ussr. Phys. Solid Earth. 1974;(11):23-36.
11. Bezrodnyj EM, Tuychiev HA. Source mechanisms of strong earthquakes of Uzbekistan. Tashkent: Fan. 1987:143.
12. Yunga SL. Methods and results of studies of seismotectonic deformations.
13. Atabekov I. Earth Core's stresses variation in Central Asian earthquakes region. Geod Geodyn. 2020;11(4):293-299. https://doi.org/10.1016/j.geog.2019.12.005
14. Argan É. Tectonics of Asia: Report at the XII Brussels Session of the International Geological Congress in 1922. Moscow; Leningrad: ONTI, 1935. 192p. https://www.livre-book.com/book/30016025/bd-d2b217f5fa653370
15. Shultz SS. Analysis of Recent Tectonics and Relief of the Tien Shan. Moscow: OGIZ, Geographiz, 1948. 224p. https://www.livre-book.com/book/30378290/6058058
16. Khamrabaev IKh. Structure of the Earth's Crust in Western Pamir Based on Complex Geological-Geophysical Data. Uzbek Geol J; 1980. 47-51p. Russion. https://www.geokniga.org/books/20300
17. Yudakhin FN, Chediya OK, Sabitova TM. Modern Geodynamics of the Tien Shan Lithosphere. Science; 1991. 192p.
18. Butovskaya EM, Atabaev KhA, Atabaeva MN. Deep Structure of the Earth's Crust in Some Regions of Central Asia Based on Seismological Survey Data. The Earth's Crust and Upper Mantle of

https://doi.org/10.61577/jgi.2025.100002

Central Asia. Moscow: Nauka; 1977. 37-53p. https://www.geokniga.org/books/24779#:=:

19. Dalimov TN, Troitsky VI. Evolutionary geology. Tashkent: Publishing House of the National University of Uzbekistan; 2005:512.
20. Ulomov VI, Danilova TI, Medvedeva NS, Polyakova TP. Seismogeodynamics of lineament structures in the mountainous regions bordering the Scythian-Turan plate. Izv-Phys Solid Earth. 2006;42:551-566. https://doi.org/10.1134/S1069351306070032
21. Map of Recent Tectonic Movements in the South of the USSR, edited by L.P. Polkanova. 1971. Scale: 1:1,000,000. https://www.geokniga.org/maps/6680
22. Map of Recent Tectonics of the USSR and Adjacent Regions, edited by N.I. Nikolaev. Scale: 1:1,000,000. 1977. http://neotec.ginras.ru/neomaps/M200_Union_1964_Neotectonics_Karta-noveyshey-tektoniki-sssr.html
23. Map of Recent Tectonics of South Asia and Adjacent Regions, edited by N.I. Nikolaev. Scale: 1:2,500,000. 1978. http://www.geokniga.org/maps/5449
24. Map of Recent Tectonics of Northern Eurasia, edited by A. Grachev. Russian Academy of Sciences, Scale: 1:1,500,000. 1997. http://neotec.ginras.ru/neomaps/M050_Euras-N_1997_Neotectonics_Karta-noveyshey-tektoniki-severnoy-evrazii.html
25. Atlas of Geological Maps of the Republic of Uzbekistan. Neotectonic Map, edited by Sh.D. Davlyatov. Scale: 1:2,500,000. 2016. http://www.geokniga.org/maps/5441
26. Troitsky VI, Sadykov YuM, Denisov RI. Towards a Map of Recent Tectonic Movements in Uzbekistan. Probl. Seismol in Uzbek. 2010;2(7):241-244. http://www.geokniga.org/maps/5449
27. Sadykov YuM, Nurmatov UA. Seismotectonics of the Western Tien Shan. Probl Seismol. 2021;3(2):61-73. UZBEK BIOLOGICAL JOURNAL 2018 №3
28. Sadovsky MA. Natural Fragmentation of Rocks. Selected Works: Geophysics and Physics of Explosion, edited by V.V. Adushkin. Moscow: Nauka, 2004. 332-335p. http://elib.biblioatom.ru/text/sadovskiy_izbrannye-trudy_2004/p332
29. Nersesov IL, Nikolaev AV, Sedova EN. Horizontal Heterogeneity of the Earth's Mantle Based on Seismic Data. Proc USSR Acad Sci. 1972;207(4):846-849. https://www.mathnet.ru/php/archive.phtml?wshow=paper&jrnid=dan&paperid=37306&option_lang=rus
30. Atabekov IU, Sadykov YM. Stress state of the Earth's crust in the Western Tien Shan in Central Asia (Uzbekistan): A mathematical stress model. Geotectonics. 2022;56(3):306-320. https://doi.org/10.1134/S0016852122030037
31. Atabekov I. Mathematical modelling of some geodynamical problems. 2023.
32. Peshkova IN. A Possible Model of the Structure of the Fergana Intermountain Basin. Rept Russ Acad Sci. 1997;355(2):230-234. http://www.geokniga.org/books/35062

https://doi.org/10.61577/jgi.2025.100002