

# Study on Interplay of tension, deformation, and ore formation

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**Abstract.** This study undertakes an in-depth exploration of the intricate relationship between gold mineralization in the Tamdytau area within Central Kyzylkum and the underlying tectonic tension and deformation processes. Additionally, the research delves into the interconnection between occurrences of gold ore deposits in Western Uzbekistan and the prevailing regional fault systems. Through thorough investigation, the study unveils compelling insights. The findings demonstrate that a substantial portion, approximately 34%, of the gold ore deposits in the region are geographically situated within zones closely aligned with regional ore-controlling faults that exhibit a predominant northwestern strike. This correlation underscores the significance of these structural features in influencing the distribution of gold mineralization. Furthermore, a detailed analysis of gold ore distribution within the Tamdytau region discloses a noteworthy trend: over 80% of the ore occurrences are strategically located within areas characterized by relatively low shear stress values and stress neutralization conditions. This observation highlights the crucial connection between the geological stress environment and the formation of gold-rich mineralization. These revelations underscore the profound role played by tectonic processes, particularly tension and deformation, in shaping the presence of gold mineralization within the study area. The intricate interplay between geological factors and mineralization patterns has far-reaching implications for the understanding of gold deposition mechanisms and the potential for uncovering valuable resources within this region.

## 1 Introduction

In recent years, Uzbekistan has experienced rapid economic development, leading to an increased focus on expanding the country's mineral resource base. This is a common challenge faced by many nations with significant mineral deposits. One of the approaches taken to address this issue is expanding the scope of exploration through the utilization of a comprehensive range of geological research methods. However, this expansion is accompanied by increased financial costs. Therefore, it is crucial to optimize exploration efforts by conducting specialized studies to identify the most promising areas with a high probability of finding valuable mineral deposits [6,7].

To achieve this, a combination of geological and structural investigations, along with tectonophysical methods, is necessary to study the formation and development mechanisms of ore-controlling structures, tectonic stresses, and crustal deformation. Prominent researchers such as F.I. Wolfson, A.V. Korolev, V.M. Kreyter, N.P. Laverov, L.I. Lukin, E.M. Nekrasev, V.A. Nevsky, V.P. Fedorchuk, V.A. Korolev, and H.A. Akbarov have made significant contributions to the field of geological and structural studies. These studies help determine the lithological, structural, and magmatic conditions that contribute to mineralization, identify indicators and controlling factors of mineralization, and develop predictive and prospecting criteria based on these findings[2,3].

In recent times, tectonophysical methods have gained importance in geological research, specifically in analyzing the stress-strain state of the Earth's crust and deciphering the formation mechanisms of geological structures[4,5]. Additionally, tectonophysical studies, including experimental modeling of tectonic stresses within ore fields and deposits, when combined with geological and structural analysis, facilitate the reconstruction of the geodynamic context during the period of ore formation (M.K. Turapov et al.) [8].

A fundamental principle of tectonophysical research, as established by M.V. Gzovsky, is the statistical significance of study results [1, 2]. This principle has been instrumental in determining the relationship between stress, deformation, and mineralization. It opens up new insights into the genesis, patterns of formation, and distribution of

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endogenous mineralization. Furthermore, the outcomes of such studies enable the development of predictive criteria and exploration guidelines. Addressing these pressing challenges is essential for the gold deposits in Western Uzbekistan, as it will contribute to strengthening the region's gold reserves [9, 10].

## 2 Materials and methods

To investigate the stress and deformation of the Earth's crust in Western Uzbekistan, a series of experiments were conducted to model tectonic stresses within structures. These modeling efforts were based on the principles established by M.V. Gzovsky and followed the methodology outlined by D.N. Osokina, which was further improved by V.A. Korolev and Sh.D. Fatkhullaev [4-7].

The structural framework of the model represented the Hercynian metallogenic epoch (C3-P1) of the region's development, during which the main metallogenic features were determined. The tectonic activity during this period was characterized by significant northwestern faults accompanied by complex transverse local structures.

The analysis of the results from modeling tectonic stresses within the region's structures revealed a wide range of variations in shear stresses, ranging from neutral ( $\tau_{max} = 0$ ) to strong ( $\tau_{max} > 22 \text{ g/cm}^3$ ). High stress values were particularly observed in the areas where faults intersected and changed their morphology, such as areas of curvature. The concentration of tangential stresses and their spatial development in these areas depended largely on the activity of the structures. The model showed that the regional northwestern faults exhibited low activity, along with their specific morphology, resulting in contrasting tension zones within these structures. Changes in tension were found to occur synchronously with changes in strain, with the occurrence of local tensile strain leading to a decrease in shear stresses, and vice versa, compressive strain leading to an increase in stresses.

The influence of external tectonic forces on tension and deformation undoubtedly impacted the geological features of the region. These effects included the formation of new structures, regional metamorphism, the emplacement of intrusive formations, and the associated endogenous mineralization. The folded northwestern and transverse northeastern faults played a significant role in these processes within the region.

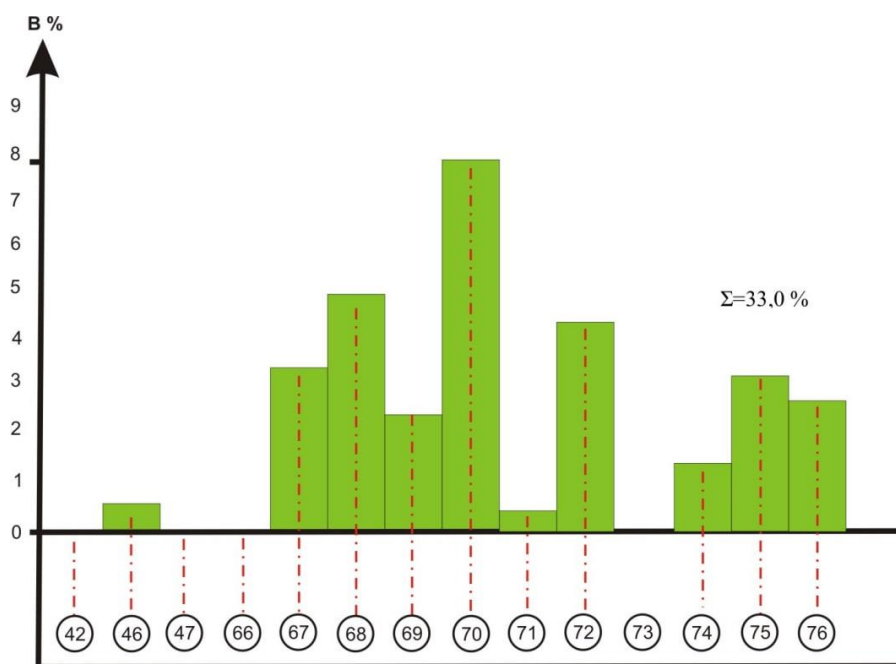
Mathematical and statistical analysis of data on the distribution pattern of gold deposits in Western Uzbekistan (as shown in Table 1 and Fig. 1) indicates that approximately 33% of all gold deposits and occurrences in the region are located within the zones of regional northwestern faults.

**Table 1.** Relationship between gold ore objects and regional faults Western Uzbekistan.

#	Name of the regional structure (numbers according to the map "Regional faults of Central Asia")	Genetic types (about M.A. Akhmadzhanov, O.M. Borisov, Zh. Yakubov, A.K. Bukharin, etc.)	Placement of gold occurrences in fault zones, %
1	North Kyzylkum 42		0
2	Bukantausky 46	uplift	0.6
3	Central Kyzylkum 47	uplift	0
4	Tamdy-Karachatyrsk and st 66	uplift	0
5	Besapano-South Fergansky 67	uplift	3.4
6	South Tamdysko-Katransky 68	uplift	5.1
7	Aristantau-Taldytsky 69	uplift	2.3
8	Auminzatau-Surmetashsky 70	uplift	≈8
9	Aktau-Turkestan 71	uplift	0.6
10	Karatau- Zarafshansky 72	uplift	4.5
11	Kulzhuktau - Zarafshansky 73	uplift	0
12	Zirabulak - Dukdan 74	uplift	1.7
13	Zirabulak - Magiansky 75	uplift	3.4
14	South Tien Shan 76	uplift	≈3.0
15	Utemergensky 112		
	Number of objects 176		≈33%

A comparative analysis of the stress-strain state of the region and the metallogenic features of gold mineralization revealed a close relationship between them. The contrasting tension and deformation within the zones of northwestern faults, particularly in localized areas of tensile deformations, significantly influenced the distribution of gold occurrences within these structures.

In the study of tectonophysical features in areas with endogenous mineralization, the question of the relationship between tectonic tension and ore formation is of utmost importance. Prominent researchers such as V.A. Korolev (1983), Sh.D. Fatkhullaev (1976), Experimental Tectonics (1983), M.K. Turapov et al. (2017, 2011), N. Dulabova et al. (2014), B.O. Zhanibekov (2019, 2022), Z. Fatkhullaeva (2022), and N.Sh. Tulyaganova (2022) have contributed to this field of study [2-7]. Tectonophysical studies conducted on gold deposits in Eastern Uzbekistan aimed to investigate the relationship between ore formation and tectonic tension. These studies revealed that all known gold deposits in the region were formed in areas where tension was minimized, with localized tensile deformations occurring amidst regional compression. This insight led to the development of forecasting and exploration criteria, which helped identify promising areas within the Kyzylalmasai, Kochbulak, and other ore fields. Moreover, these findings provided new impetus for the development of tectonophysical research in other regions of Uzbekistan, including the Central Kyzyl Kum, which hosts unique gold deposits [10].

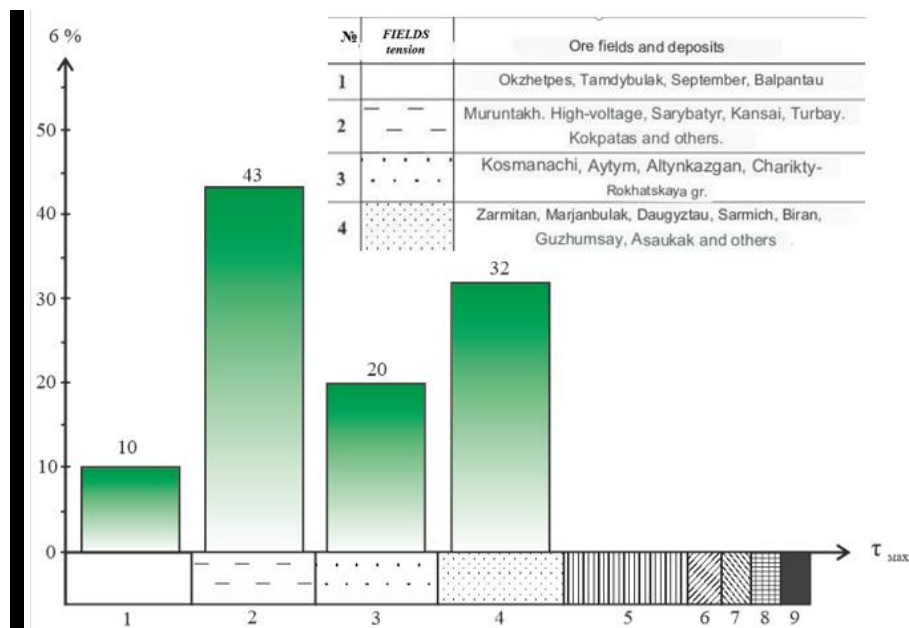


**Fig. 1.** Histogram of the location of ore objects in the zones of regional faults in Western Uzbekistan.

M.V. Gzovsky formulated five principles of tectonophysical modeling: similarity, selectivity, separation, approximation, and statistical validity. The principle of similarity, ensuring that the model resembles the natural object being studied, must always be observed in modeling. The remaining principles guide the gradual and consistent selection and adjustment of the model to match the real natural object, as noted by M.V. Gzovsky, V.G. Guterman, and A.V. Mikhailova in their work on modeling the structures of the Earth's crust [3-9].

### 3 Results and discussion

Following the principles of M.V. Gzovsky's modeling approach, tectonophysical studies were conducted on the western territory of Uzbekistan, specifically in its individual ore-bearing areas such as Bukantau, Tamdytau, Beltau, Auminzatau, and others. Based on the principle of statistical validity of modeling results, comparisons were made between the experimental data and the gold metallogeny of Western Uzbekistan, particularly focusing on Tamdytau. The results of this work (Fig. 2) revealed that areas with low indicators of tension, even up to complete neutralization, were most favorable for the manifestation of gold mineralization at the scale of ore fields and deposits. A comparative analysis of the experimental results with gold occurrences in Western Uzbekistan showed that 73% of all gold ore fields and deposits are located in areas with low stress values, while 32% of ore objects are spatially associated with areas of very moderate stress. As stress and deformation increase, the manifestation of gold mineralization diminishes.

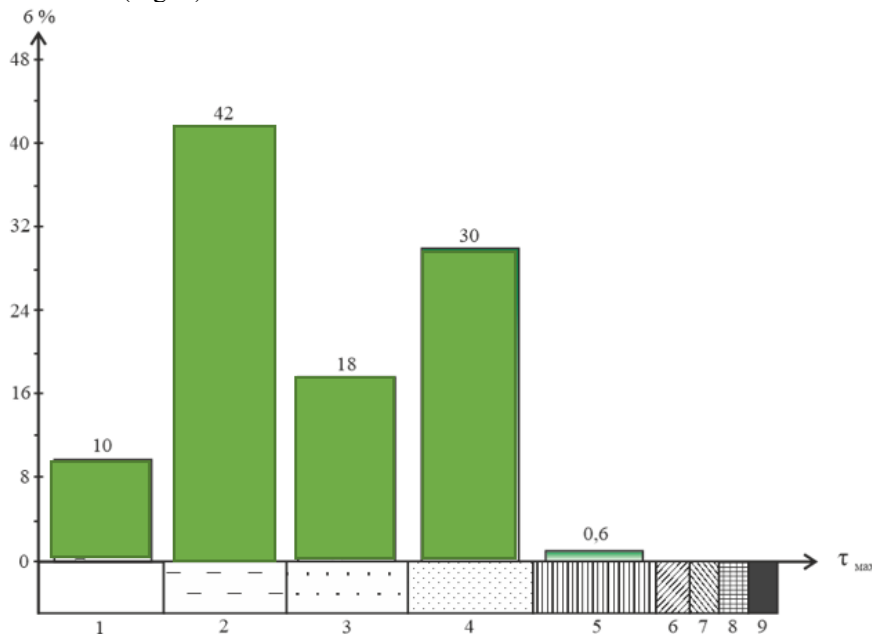


**Fig. 2.** Distribution of gold deposits in Western Uzbekistan in shear stress fields.

The value of the maximum shear stress can be classified as follows (in order of increasing  $\tau_{max}$  values):

- No stress.
- 2-3. Fields of weak stresses (3.2-5.6 g/cm<sup>2</sup>).
- Moderate stress range (8.3 g/cm<sup>2</sup>).
- Moderate stress level (10.0 g/cm<sup>2</sup>).
- Moderately strong stresses (13.7 g/cm<sup>2</sup>).
- 7-8. Strong stress range (17.6-20.0 g/cm<sup>2</sup>).
- Maximum stress level (>22.0 g/cm<sup>2</sup>).

A similar distribution pattern of gold deposits in relation to shear stresses is observed in Western Uzbekistan, particularly in the Tamdytau ore-bearing area (refer to Fig. 3). Approximately 70% of all gold deposits in Tamdytau are associated with neutral zones and weak stress fields, while around 30% of ore occurrences are located in areas of moderate tangential stresses (Fig. 3).



**Fig. 3.** Distribution of Tamdytau gold deposits in shear stress fields (data on old occurrences based on stock materials)

The correct value of the maximum shear stress, in order of increasing  $\tau_{max}$ , is as follows:

- 1 - No stress
- 2, 3 - Fields of weak stresses (3.2-5.6 g/cm<sup>2</sup>)
- 4 - Weight of moderate stresses (8.3 g/cm<sup>2</sup>)
- 5 - Moderate stresses (10.0 g/cm<sup>2</sup>)
- 6 - Moderately strong (13.7 g/cm<sup>2</sup>)
- 7, 8 - Strong (17.6-20.0 g/cm<sup>2</sup>)
- 9 - Maximum stresses (>22.0 g/cm<sup>2</sup>)

The relationship between tectonic stresses of a regional nature in Western Uzbekistan and its gold ore manifestations remains significant in the local Tamdytau ore-bearing area. This relationship is crucial when prospecting for gold across Western Uzbekistan, utilizing modeling results as search criteria.

The findings from studying the connection between gold ore occurrences in Tamdytau and tectonic stress have confirmed the statistical data linking gold mineralization to crustal tension in Western Uzbekistan, thereby enhancing their reliability. Additionally, experimental work on modeling tectonic stresses at a local level in the Tamdytau structures has yielded data on the tectonic stress present during the period of ore formation (refer to Fig. 4).

The research results indicate that more than 90% of all Tamdytau gold deposits and ore occurrences are situated in areas characterized by either the absence of stress or the presence of low stress values. Approximately 8% of the Tamdytau gold deposits and ore occurrences are found in fields with moderate stress values.

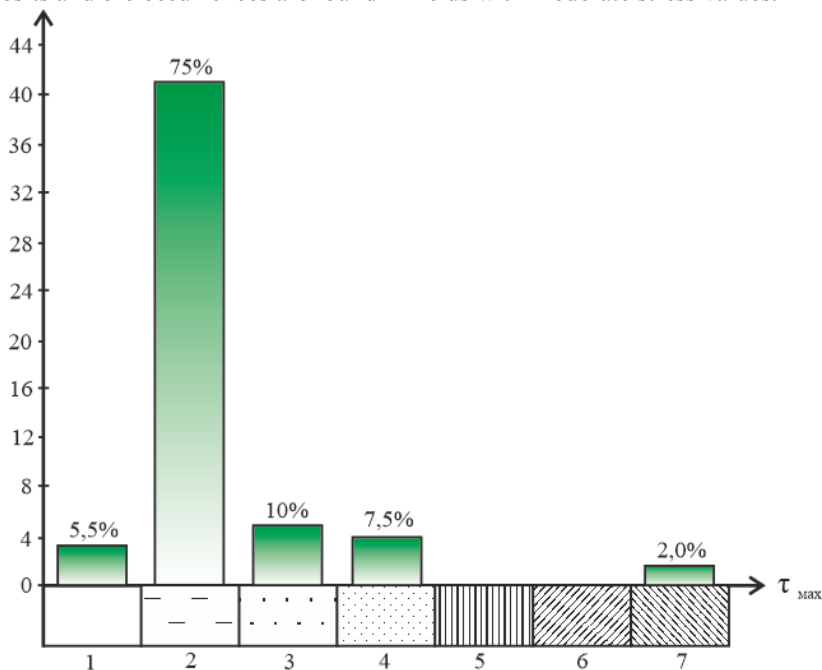


Fig. 4. Distribution of gold occurrences in Tamdytau in shear stress fields.

The correct value of the maximum shear stress, in order of increasing  $\tau_{max}$ , along with their corresponding stress ranges, is as follows:

- 1 - No stress
- 2, 3 - Fields of weak stresses (3.2-5.6 g/cm<sup>2</sup>)
- 4 - Weight of moderate stresses (8.3 g/cm<sup>2</sup>)
- 5 - Moderate stresses (10.0 g/cm<sup>2</sup>)
- 6 - Moderately strong (13.7 g/cm<sup>2</sup>)
- 7 - Strong (17.6-20.0 g/cm<sup>2</sup>)

#### 4 Conclusions

The analysis of metallogenic studies and the investigation of tectonophysical features in Western Uzbekistan, including its local ore-bearing area, have provided valuable insights into the relationship between gold

mineralization and tension and deformation. This analysis has been conducted at various scales, enabling an objective assessment of the boundaries associated with different stress values and deformation patterns. Furthermore, the correlation between tectonophysical features and gold mineralization manifestations in Western Uzbekistan has been established.

The findings of these studies have significant implications for predictive prospecting activities focused on gold exploration in the region. By utilizing the results of these investigations, prospectors and researchers can enhance their understanding of the spatial distribution of gold deposits and ore occurrences. This knowledge can help guide future exploration efforts and improve the efficiency and success rate of gold prospecting activities in Western Uzbekistan.

Overall, the integration of metallogenic studies and tectonophysical analyses provides a comprehensive framework for evaluating the relationship between gold mineralization and geological structures. The application of these research results in predictive prospecting can contribute to the identification of prospective areas with higher potential for gold deposits, supporting effective resource exploration and development in Western Uzbekistan.

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