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Role of strike-slips and graben-rifts in controlling oil and gas reservoirs in deep horizons of the Russko-Chaselsky Ridge (West Siberian Province)

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Abstract

The study of the geological setting features of the West Siberian Oil-and-Gas Province (OGP) is relevant for establishing the relationship between the spatial distribution of local strike-slip dislocations (Russko-Chaselsky Ridge) and the structure of the regional Pai-Khoi-Altai shearing zone. The work aims to identify the regularities of hydrocarbon accumulations location associated with fault systems of this zone. The paper presents the results of studies aimed at assessing the nature of the Earth crust disturbance within the regional Pai-Khoi–Altai shearing zone and the prerequisites for the occurrence of hydrocarbon accumulations within it. A complex set of regional and detailed geophysical data, including 2D and 3D seismic surveys and digital models of gravity and magnetic fields, was used as a factual basis. Based on these materials, cross-sections and maps were drawn showing the structural features of the sedimentary cover and consolidated basement, and an analysis of the nature of the Earth crust disturbance within the shearing zone was performed. It was revealed that the disjunctive dislocations of the regional Pai-Khoi–Altai shearing zone have a characteristic morphology described by a right-lateral strike-slip (dextral) fault strain ellipsoid. Within the Russko-Chaselsky Ridge, patterns were identified in the manifestation of strike-slips and graben-rifts systems caused by the tectonic activity of the regional Pai-Khoi–Altai shear. The shearing zone, en echelon faulting, and associated Riedel shears constitute a single, hierarchically subordinate system of the upper Earth crust disturbance. It is characterized by the development of en echelon system of disturbance zones in the platform cover and the upper part of the consolidated basement, interpreted as Riedel shears of prevailing submeridional strike. Based on the interpretation of seismic cross-sections along the Riedel shears, “flower structures” extending from the Lower Cretaceous to the top of the Paleozoic were distinguished. Structures of this type, located within the West Siberian Oil-and-Gas Province and represented by dislocation systems, may act as drainage in further substantiation of the mechanisms of migration and accumulation of hydrocarbons.

Keywords

shear structures (strike-slips), graben-rift, Western Siberia, oil and gas reservoirs, gravity anomalies, magnetic anomalies, seismic surveying, potential fields, Riedel shears

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ГЕОЛОГИЯ МЕСТОРОЖДЕНИЙ ПОЛЕЗНЫХ ИСКОПАЕМЫХ

Научная статья

Роль сдвиговых дислокаций и грабен-рифтов в контроле нефтегазоносности глубинных горизонтов Русско-Часельского вала (Западно-Сибирская провинция)

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Аннотация

Изучение особенностей геологического строения Западно-Сибирской нефтегазоносной провинции (НГП) актуально для установления взаимосвязи между пространственным распределением локальных сдвиговых дислокаций Русско-Часельского вала и структурой региональной Пай-Хой–Алтайской сдвиговой зоны. Цель работы – выявление закономерностей локализации УВ-скоплений, ассоциированных с разрывными нарушениями этой зоны. В статье представлены результаты исследований, направленных на оценку характера деструкции земной коры в пределах региональной Пай-Хой–Алтайской сдвиговой зоны и предпосылок локализации месторождений углеводородов в ее пределах. В качестве фактологической основы задействован комплекс региональных и детальных геофизических данных, включающий 2D и 3D сейсморазведку, цифровые модели гравитационного и магнитного полей. На основе этих материалов были построены разрезы и карты, отображающие особенности строения осадочного чехла и консолидированного фундамента, выполнен анализ характера деструкции земной коры в пределах сдвиговой зоны. Выявлено, что разрывные дислокации региональной Пай-Хой–Алтайской сдвиговой зоны имеют характерную морфологию, описываемую эллипсоидом деформаций правостороннего сдвига. В пределах Русско-Часельского вала определены закономерности проявления системы сдвиговых дислокаций и грабен-рифтовых структур, обусловленных тектонической системой регионального Пай-Хой–Алтайского сдвига. Сдвиговая зона, оперяющие разломы и связанные с ними сколы Риделя составляют единую иерархически подчиненную систему деструкции верхней коры. Для нее характерно развитие эшелонированной системы зон деструкции платформенного чехла и верхней части консолидированного фундамента, интерпретируемой как трещины Риделя с преобладанием субмеридионального простирания. По результатам интерпретации сейсмических разрезов вдоль трещин Риделя выделяются «структуры цветка», простирающиеся от нижнего мела до кровли палеозойских отложений. Структуры этого типа, локализованные в пределах Западно-Сибирской нефтегазовой провинции и представленные системами дислокаций, могут выступать дренажом при дальнейшем обосновании механизмов миграции и аккумуляции месторождений углеводородов.

Ключевые слова

сдвиговые структуры, грабен-рифт, Западная Сибирь, нефтегазоносность, гравитационные аномалии, магнитные аномалии, сейсморазведка, потенциальные поля, трещины Риделя

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Sekerina D.D., Saitgaleev M.M., Senchina N.P., Glazunov V.V., Kalinin D.F., Kozlov M.P., Ismagilova E.I. Role of strike-slips and graben-rifts in controlling oil and gas reservoirs in deep horizons of the Russko-Chaselsky Ridge (West Siberian Province). *Mining Science and Technology* (*Russia*). 2025;10(2):109–117. https://doi.org/10.17073/2500-0632-2025-02-399

Introduction

We examined the geological setting features of the West Siberian Oil-and-Gas Province (OGP) in order to establish the relationship between the spatial distribution of local strike-slip dislocations (within the Russko-Chaselsky Ridge) and the dislocation system of the regional shearing zone in connection with the study of the regularities governing the location of hydrocarbon accumulations associated with a complex system of disjunctive dislocations that are part of the regional Pai-Khoi-Altai shearing zone [1, 2].

Within the West Siberian OGP, the bulk of the identified hydrocarbon accumulations [3–5] are confined to Cretaceous sediments. The Bazhenovsky horizon is considered to be the oil source strata; the Lower Cretaceous terrigenous rocks act as the reservoir; the Podachimovsky horizon mudstone is the impermeable layer [6–8]. The mechanism of hydrocarbon migration can be largely explained by the development of a system of disjunctive dislocations. Many researchers studied the nature of shear dislocations in consolidated basements and the lower parts of the sedimentary cover of the West Siberian geosyncline [9, 10]. For instance, A.E. Kontorovich distinguished between major shear dislocations of different directions (first order) penetrating into the Lower Cretaceous horizons and secondary shears (second order) mapped in the Cenozoic sequence [3, 11, 12].

A.I. Timurziev, based on an in-depth study of the 2D and 3D seismic survey data, concluded that regional shearing zones are widely manifested in the northwestern part of the West Siberian geosyncline [2, 9]. The author notes that the results of the 2D seismic surveys do not always accurately reflect horizontal shear structures (strike-slips), unlike the results of the detailed 3D seismic surveys [11, 13]. An important feature of the shears, in his view, is the almost complete absence of vertical displacements at the level of the uppermost consolidated basement.

Detailed studies within the Ety-Purovsky accumulation have shown that regional shears are framed by a system of en echelon tension stress and shearing dislocations. Within the shearing zones, based on the 3D seismic data, the author has identified a system of northwestward strike-slips and en echelon northeastward strike-slips on the sides and in the spaces separating the major strike-slips [9–13].

In our research, we considered the features of the deep structure of the regional Pai-Khoi–Altai shearing zone, which, judging by a complex of geological and geophysical data, extends from the Altai-Sayan folded area to the Pai-Khoi. The zone includes the main fault (geosuture) and a system of en echelon extension faults and strike-slips (shears) [14, 15] (Fig. 1). This system of tectonic dislocations developed against the backdrop of a consolidated basement formed by formations of different age, from the Yenisei (Baikalides), Kazakhstan and Altai-Sayan (Caledonides), Ural and Central-Western Siberian (Hercinides) folded areas [14].

Research techniques and factual material

The area of our detailed research (Fig. 1, *a*), including the outline of the Russko-Chaselsky Ridge, is characterized by a high level of geological and geophysical knowledge [16]. As a factual basis for the research, we used the results of seismic surveys, deep drilling data, and potential geophysical fields data borrowed from the Gravimag database at a scale of 1 : 200,000 [16, 17].

The study area at local level was selected depending on the seismic cross-section outlines. To simulate shear dislocations and investigate the structure of the basement and sedimentary cover within the study area, we performed a series of procedures: calculation of potential field transformants [18], including factorization into regional and local components, calculation of gradients, etc. [19, 20]. To estimate the amplitudes of tectonic deformations, seismic cross-sections were filtered using surface-consistent procedures, adaptive noise suppression, 5D regularization, and Kirchhoff depth migration (using OVT panels), as well as post-processing[1] [21]. In addition, the results of solving inverse problems of gravity and magnetic surveys, etc. were used (Fig. 2) [21]. The methodological approach involved applying a multi-level data processing scheme at regional and local levels to identify characteristic patterns of subordination of geological structures.

A.I. Timurziev found similar horizontal shear structures (strike-slips) are manifested in the sedimentary cover by linear en echelon systems of downthrow faults and thrust faults; the en echelon faults are grouped into a linear zone of NW strike (310–320°) with a width ranging from 1.0–1.5 km in the lower part of the sedimentary cover to 5.0–6.5 km in the Upper Cretaceous top. Along the strike, the suture zone comprises grabens and depressions of shear extension [9, 22].

A qualitative interpretation of the transformants [18, 23] allowed to identifying elongated positive anomalies of the gravitational and magnetic fields of submeridional strike in the central part of the

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detailed study area, which, in our opinion, are manifestations of rift structures [23–25]. On the structural-tectonic diagrams compiled based on these data (see Fig. 2), first-order shear dislocations (strike-slips) have a predominantly northwestern strike, while second-order rift structures are oriented northeastward and located in the space between the major shear dislocations [23, 26, 27].

The manifestations of these dislocations at a detailed level in seismic cross-sections of the Bazhenovsky reflective horizon interval (Fig. 3) are expressed in graben-rift structures, traced in the form of "Riedel shears" oriented at an angle of 30° to the main shear axis [28, 29].

According to most researchers, the main shear dislocations are deeply seated [30, 31]. The extension structures are most likely seated near the surface [32]. In this regard, we studied geological and geophysical cross-sections based on reference seismic profiles [11, 15]. In the interval between 1,000 and 2,000 ms, a system of disjunctive dislocations with a characteristic "flower structure" morphology can be traced (Fig. 4) [14]. Above this interval, only anticline folds are manifested that indirectly confirms the assumption of an attenuation of tectonic deformations in the Upper Jurassic sediments [31, 33].

The Figure demonstrates the strike-slips joining en echelon the plane of major shear in a fan-like manner [1, 34]. The appearance of the "flower structures" indicates the strike-slips (shears) of northeastern strike [35, 36] that allows assuming trans-tensional nature of the strike-slips [13, 34]. The roots of these faults can be traced below the uppermost basement (below 6 km) [37, 38].

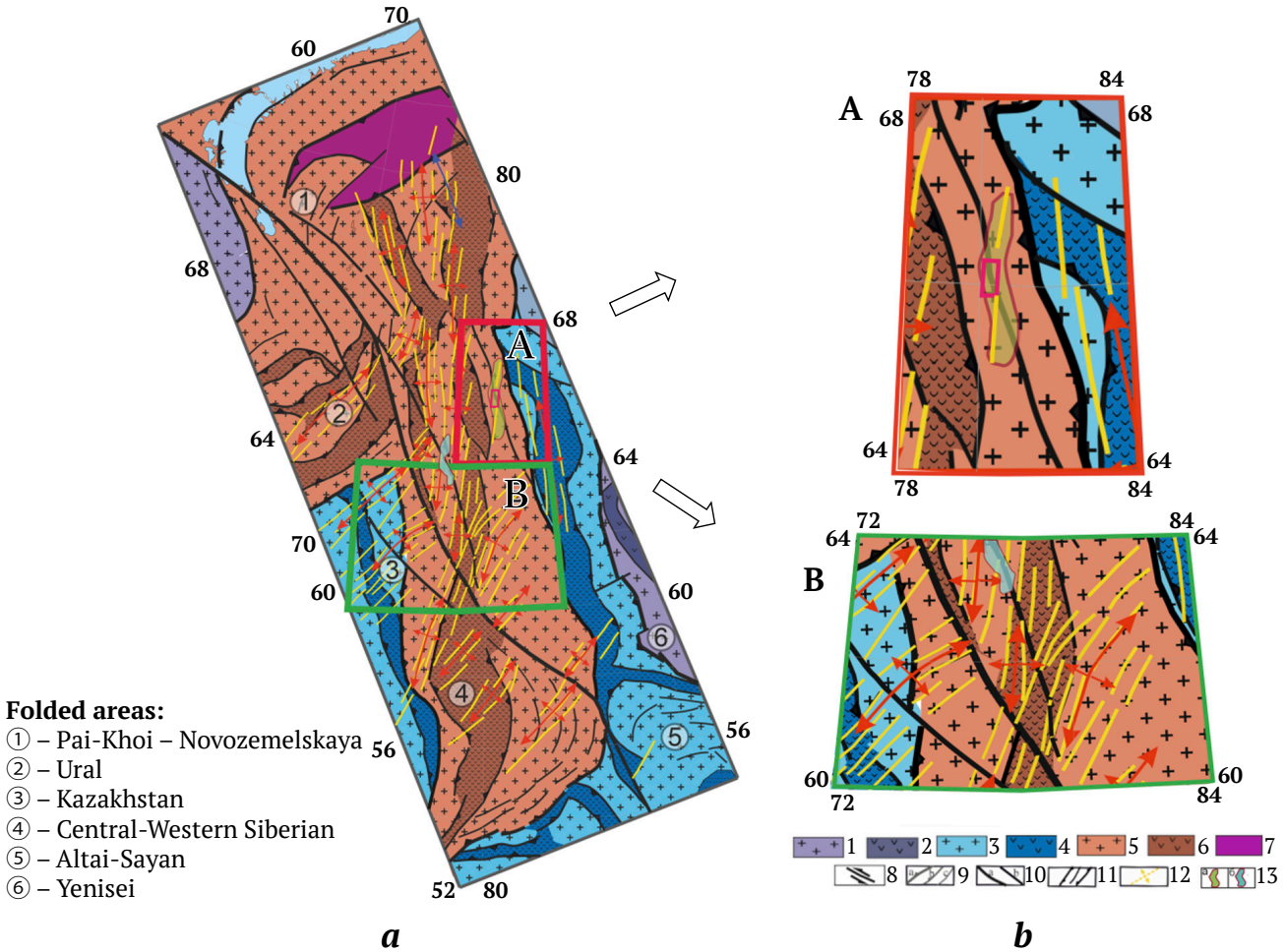

Fig. 1. Fragment of a map of the deep geological setting of the consolidated basement of the West Siberian OGP with the location of the study area (*A*), the territory of the Russko-Chaselsky Ridge, and with the outline of the neighboring area (*B*), within which the Ety-Purovsky Ridge is located [15]: *1–7* – structural and material subdivisions of the consolidated crust: *1–2* – Epibaykal folded areas (*1* – blocks, *2* – interblock zones), *3–4* – Epicaledonian folded areas (*3* – blocks, *4* – interblock zones), *5–6* – epihercinian folded areas (*5* – blocks, *6* – interblock zones), *7* – ancient platforms; *8–11* – disjunctive dislocations: *8* – the Pai-Khoi – Novozemelsky shear displacement direction, *9* – en echelon disjunctive dislocations, *10* – boundaries of interblock suture zones, *11* – rift boundaries, *12* – lineaments and rift development direction, *13* – Ridge outlines (*a* – Russko-Chaselsky, *b* – Eti-Purovsky)

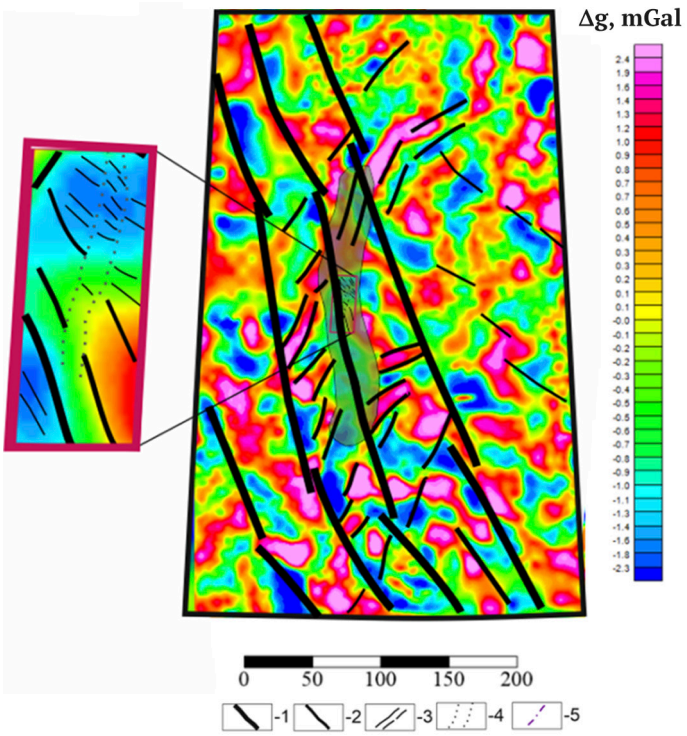

Fig. 2. Results of interpretation based on potential fields (according to the map of the local component of the gravitational field) [compiled by the authors]: *1* – boundaries of rift structures (I rank); *2* – strike-slip; *3* – rift structures (II rank); *4* – presumed boundaries of Riedel shear development zone; *5* – axial direction of Riedel shear development

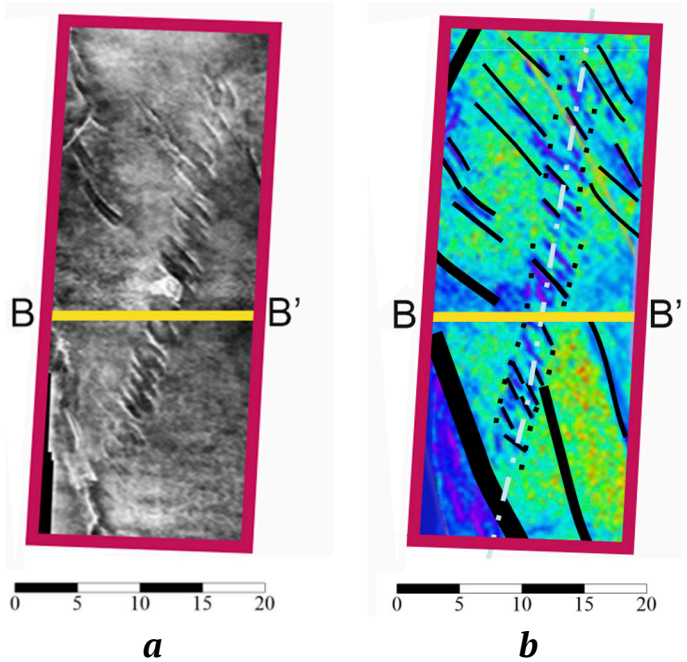

Fig. 3. Interpretation within the detailed study area with the position of seismic profile B–B' (highlighted in yellow), performed on the basis of a horizontal cross-section of the total 3D cube in the interval of the Bazhenovsky reflective horizon (characteristic dimensions of kilometers) – *a*, and the amplitude distribution diagram along the seismic cross-section – *b* [compiled by the authors]

The results obtained confirm that the manifestation of rifts and strike-slips in the form of Riedel shears creates favorable conditions for the migration and accumulation of hydrocarbons in traps [39]. For example, Riedel shears can serve as channels for hydrocarbon migration and also change the mechanical properties of rocks that in turn affects their ability to retain oil and gas and characterize the novelty of the authors' research [2, 40].

The practical application of the results obtained lies in the use of structural factors (Riedel shears, "flower structure") in solving predictive problems using both geophysical and geological-structural criteria for determining oil and gas potential.

Conclusion (findings)

Thus, it can be concluded that the disjunctive dislocations of the regional Pai-Khoi–Altai shearing zone have a characteristic morphology described by a right-lateral strike-slip (dextral) fault strain ellipsoid.

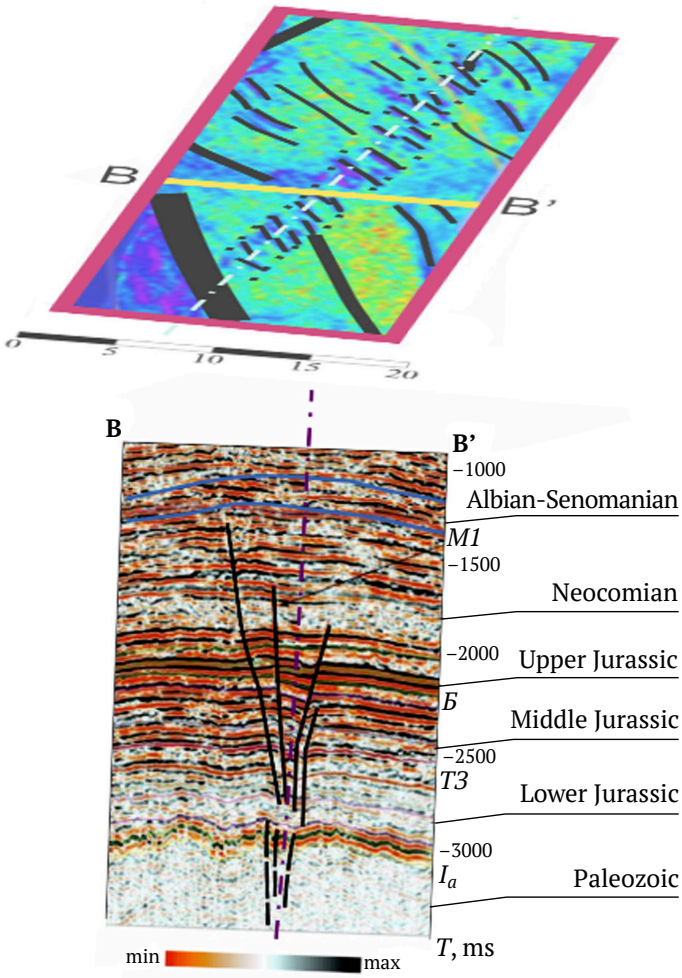

Fig. 4. The manifestation of the "flower structure" and Riedel shears based on seismic data interpretation (see legend to Fig. 2) [compiled by the authors]

The shearing zone, en echelon faulting, and associated Riedel shears constitute a single, hierarchically subordinate system of the upper Earth crust disturbance and are promising for further study of hydrocarbon migration and accumulation mechanisms [5].

Within the Russko-Chaselsky Ridge, patterns were revealed in the manifestation of strike-slips and graben-rifts systems caused by the tectonic activity of the regional Pai-Khoi–Altai shear; This zone is characterized by the development of en echelon system of disturbance zones in the platform cover and the upper part of the consolidated basement, interpreted as Riedel shears of prevailing submeridional strike.

The main shearing zone within the study area is 6 km long and 0.8 km wide. In the cross-section, an interconnection between disjunctive dislocations can be traced, in the distribution of which a “flower structure” can be identified, extending from the Lower Cretaceous to the uppermost Paleozoic and demonstrating a fan-shaped orientation of faults (within the studied area).

Structures of this type, located within the West Siberian Oil-and-Gas Province and represented by dislocation systems, may be considered as drainage in further substantiation of the mechanisms of migration and accumulation of hydrocarbons.

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