

Fracture system influence on the reservoirs rock formation of Ordovician-Devonian carbonates in West Siberia tectonic depression

A E Koveshnikov^{1,2}, A C Nesterova¹, T F Dolgaya³

¹ National Research Tomsk Polytechnic University, Tomsk, Russia

² Tomsk Division of Trofimuk Institute of Petroleum-Gas Geology and Geophysics of the Siberian Branch of the RAS, Tomsk, Russia

³ National Research Tomsk Polytechnic University, Tomsk, Russia

E-mail: ^{1,2}Kovesha@mail.ru, ¹As_nesterova@mail.ru

Abstract. During the Paleozoic period from the beginning of the Cambrian to the end of the Carboniferous in the boundaries of the West Siberia tectonic depression there occurred the sea, where the carbonate platforms were formed by the limestones accumulation. All the area at the end of the Carboniferous period was turned to land. Resulting from Gertsynskaya folding in the times of Permian – Triassic the formed deposits were folded and denudated to a considerable extent. Besides, the reservoir rocks of the crust of weathering including redeposited one, were formed as a result of hypergenesis, during the continental stand of the area in the near-surface zone. A new geological prospecting unit has been suggested which underlies these crusts of weathering and formed during fracture tectonic processes with hydrothermal-metasomatic limestones reworking and the processes of hydrothermal leaching and dolomitization. So, in the carbonate platforms the system of fissure zones related to tectonic disturbance was formed. This has a dendrite profile where the series of tangential, more thinned fractures deviate from the stem and finish in pores and caverns. The carbonate platforms formation in the West Siberia tectonic depression has been analyzed, their dynamics and gradual increasing from the minimal in Ordovician and Silurian to maximal at the end of the Late Devonian has been shown.

1. Introduction

West Siberia tectonic depression is one of the most promising sources of oil and gas stock addition for the whole territory of Russia. Here, the carbonate formations are thought to be promising but are not explored properly [1]. They are characterized by the following varieties: carbonate, carbonate-flinty and carbonate-clayey rocks, which have complex history of formation and secondary processes of transformation.

The concept of Paleozoic reservoir rock formation in the near-surface zone, where the Paleozoic deposits occurred on land is a generally accepted point of view. In this area during the Permian – Triassic period or the continental stand time in the near-surface zone which is also called the oil-bearing horizon of the contact zone for the Paleozoic and overlapping Mesozoic deposits [9] there formed the crusts of weathering including redeposited ones.



They occurred resulting from hypergenesis processes [3], and, according to this point of view, all newly - formed Paleozoic reservoir rocks and oil\gas deposits relate to the above mentioned crusts of weathering.

Reservoir rocks formation mechanism has been suggested [2]. This is provided in the unweathered near-surface zone limestones, located lower the oil-gas bearing horizon of the contact zone. These became the reservoir rocks of the fissured – porous - cavernous type as a result of fissure-hydrothermal-metasomatic processes.

The oil-bearing horizon of the contact zone was formed in the following way. After Gertsynskaya folding phenomena in the boundaries of the West Siberia tectonic depression [2] the vast synclinorium and anticlinorium zones were formed [2], which are characterized by the syncline and anticline folds of the second and third order (like Mezhovskiy medial massif) – (Fig. 1B). These are mostly surrounded by the clayey-flinty rocks which are modified, magmatic and metamorphosed sedimentary terrigenous rocks of the Proterozoic period (Fig. 1B). Synclinorium zones of the major order (Fig.1) were formed in the pre-Jurassic exposure areas of the spatially linked syncline areas (like Mezhovskiy medial massif). Anticlinorium zones were formed in the areas characterized by Proterozoic period rocks. These had less structures like Mezhovskiy medial massif had (generally more uplifted). Then, with the further formation of the tectonic depression in the boundaries of the West Siberia depression and sediment accumulation in the sea of the Jurassic-Paleogene period, these Paleozoic modified rocks due to the sea bottom subsidence were transformed by the hydrothermal secondary-katagenesis processes [3, 4] (resulting in reservoir rock formation of the fissured hydrothermal – metasomatic genesis).

The described processes relate primarily to the carbonate rocks. So, knowledge of their formation territory and the age interval in the boundaries of the West Siberia allow to determine the most promising areas of the reservoir rocks likely to be formed and oil\gas deposits in the carbonate rocks formed by the above mentioned scheme.

2. Research methods

To identify the Paleozoic deposits of various ages likely to be expanded through the West Siberia territory, the following approach has been applied [8], where the Paleozoic deposits are characterized as the carbonate-clayey formations of the Paleozoic age, folded into syncline and anticline major and the third-order folds. As described in [2] the whole territory of the West Siberia depression with the Gertsynskaya folding had great synclinorium and anticlinorium major folds to be formed (Fig. 1A) and described in [2]. The areas with the prevalence of synclinorium minor and the third-order structures in the territory make synclinoria; the Paleozoic profile is mostly preserved (Fig.1A). The areas with the exposures of the modified magmatic and the metamorphosed terrigenous Proterozoic aluminosilicate rocks are of anticlinoria (Fig.1A). So, we show the areas, where the Paleozoic profile is mostly preserved in the West Siberia boundaries. It is the area where oil\gas fields are most likely to be opened. These were formed by the above described scheme for reservoir rocks of the fissured hydrothermal – metasomatic genesis.

To study the extent area of the carbonate formations in West Siberia depression that were formed in Middle-Late Devonian period, the paleogeography reconstruction method has been applied. Based on the identified data [10] on lithological composition and the thickness of the Paleozoic deposits opened-up by drilling, the deposits expansion paleomaps for Ordovician and Silurian, Low-Middle-Late Devonian periods (Famennian and Frasnian) have been made (Fig.2). While correlating the data in Fig.1 and Fig.2 we drew a conclusion that there is

potential for reservoir rocks identification in some areas of the West Siberia depression. These were formed according to the general point of view, i.e. in oil-gas bearing horizon of the contact zone (synclinerium zones), as well as in the carbonate rocks due to the fissured hydrothermal – metasomatic processes of Paleozoic rocks (pre-Jurassic carbonate rocks exposure zone).

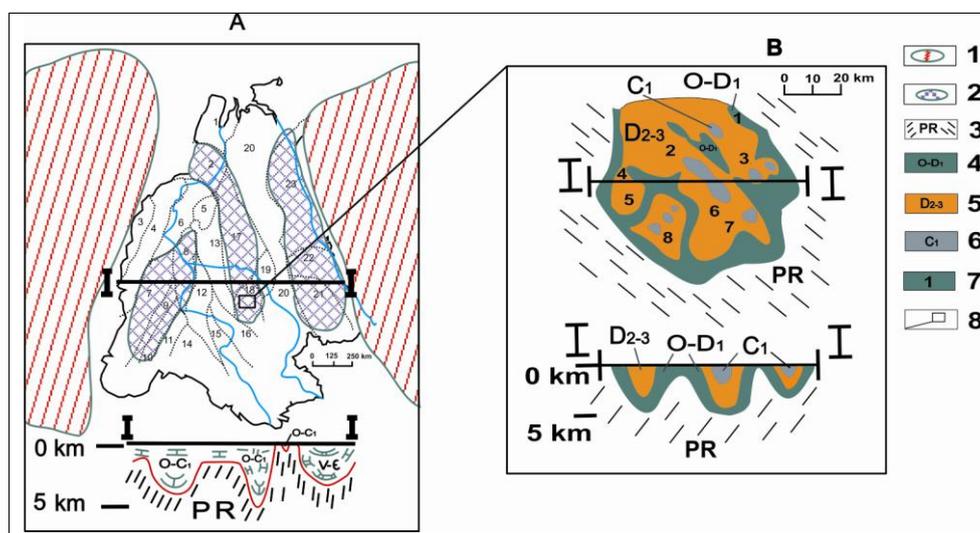


Fig1.A. Paleozoic deposits of West Siberia depression - synclinerium and antinclinorium folded. Profile schematic according to I – I line. Legend: 1. Areas of Paleozoic deposits with thickness of more than 500 m, 2. Baikalite development areas. Structurally -facial areas: 1 – Bovanenkovskiy; 2 – Novoportovskiy; 3 – Tagilskiy; 4 – Beryozovo-Sartynyinskiy; 5 – Yarudeiskiy; 6 – Sherkalinskiy; 7 – Shaimskiy; 8 – Krasnoleninskiy; 9 – Tyumenskiy; 10 – Kosolapovskiy; 11 – Uvatskiy; 12 – Salymskiy; 13 – Ust-Balykskiy; 14 – Ishimskiy; 15 – Teverizskiy; 16 – Tuisko-Barabinskiy; 17 – Varyeganskiy; 18 – Nyurolskiy; 19 – Nikolskiy; 20 – Kolpashevskiy; 21 – Vezdekhodniy; 22 – Tyiskiy; 23 – Yermakovskiy .

B. Paleozoic deposits of Mezhovskiy medial massif. Nyurolskiy structurally-facial areas synclinerium folded. Legend: 1. Baikalite development areas. 2. Synclinerium zones of Gertsynskaya folding. Rocks: 3. Cambrian – Low Devonian; 4. Middle-Upper Devonian; 5. Low-Middle Carboniferous; 6. Proterozoic. 7. Mezhovskiy medial massif location in the boundaries of Nyurolskiy structurally-facial area. 8. Oil-gas fields: 1 – Severo-Ostaninskoye, 2 – Gerasimovskoye, 3 – Ostaninskoye, 4 – Urmanskoye, 5 – Archinskoye, 6 – Severo-Kalinovoye, 7 – Kalinovoye, 8 – Nizhne-Tabaganskoye.

3. Reservoir rock formation scheme

The whole territory of the West Siberia depression according to [10] is subdivided into 23 structurally-facial areas which have their own scheme of Paleozoic rocks formation. This includes the lithological composition of rocks, fundamental secondary processes of transformation and the identified data of paleontologically characterized age (Fig.1, 2).

Reservoir rocks of Paleozoic deposits are characterized by the limestones transformed by the secondary processes of hydrothermal dolomitization as well as of hydrothermal leaching resulting in voids formation. Limestone accumulations produce large platforms (which are

called carbon-bearing platforms) in terms of area and thickness. To analyze Paleozoic complex potentials for oil\gas field exploration which are assigned to these carbon-bearing platforms, the series of paleogeographical maps for various rock ages have been made (Fig.2) [6, 7].

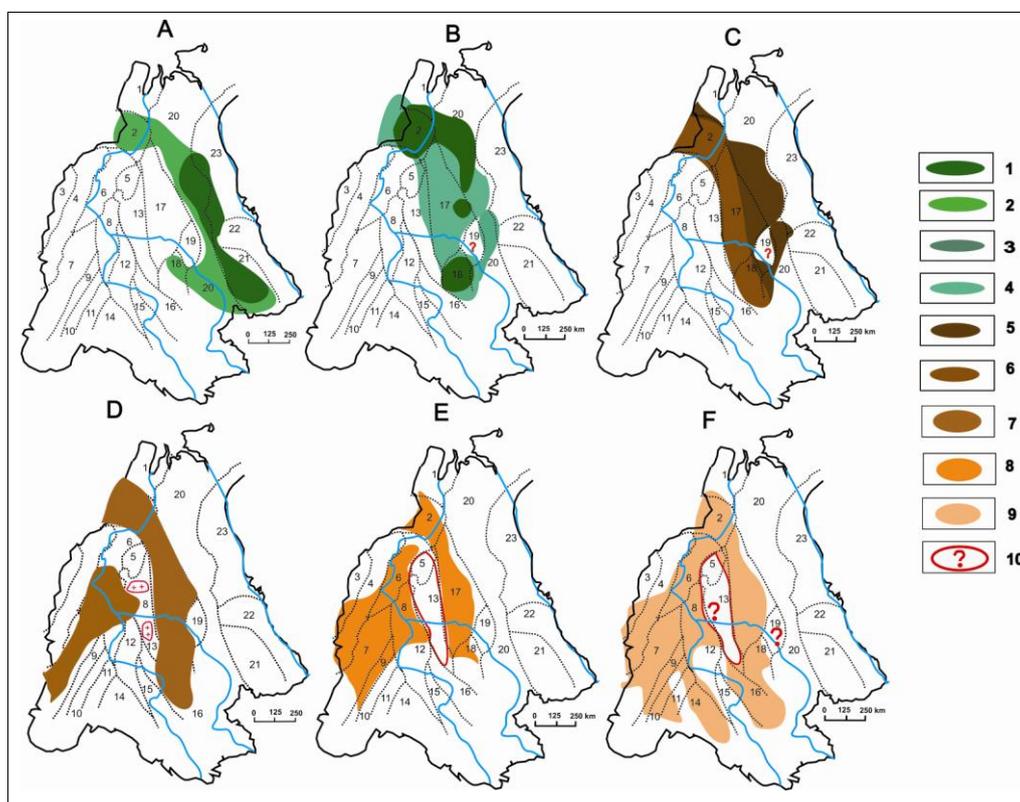


Fig. 2. Carbon-bearing platforms accumulation in the boundaries of the West Siberia depression in: A – Ordovician; B – Silurian, C – Low Devonian; D – Middle Devonian; E – Middle Devonian, Frasnian, F – Late Devonian, Famennian. Legend: Deposits: 1– Low Ordovician; 2– Middle and Upper Ordovician; 3 – Low Silurian; 4 – Upper Silurian; 5 – Low Devonian; 6 – Low Devonian, Emsian; 7 – Middle Devonian; 8 – Upper Devonian, Frasnian; 9 – Upper Devonian, Famennian, 10 – deposits are not identified by drilling.

Synclorium zones alternate with anticlinorium ones (Fig.1A). Three synclorium folds separated by anticlinorium zones have been identified. These will be largely destroyed by the denudation processes (Kolpashevskiy structurally-facial area). All Paleozoic deposits are dissected by the fault lines striking to the north-east and north-west.

Paleogeographical maps have been made to identify the territory for carbon-bearing platforms accumulation of various ages. These show the expected development of the platforms in Ordovician (Fig.2A), Low Devonian (Fig.2C), Middle Devonian (Fig.2D), Upper Devonian (Frasnian) (Fig.2E), and Upper Devonian (Famennian) (Fig.2F).

The carbonate formations by their petrophysical properties (shown above) [5], from

Ordovician to Late Devonian have allied parameters and differ in details, which characterize the organic remains complex forming limestones of various ages. Integrally, the void geometrization is subjected to the secondary processes activity spatially related to the faults. The tangential fractures, feathering the faults, are concluded by the crazes, effective fractures surrounded in the adjacent rock by the pores and caverns resulting from hydrothermal leaching and dolomitization. Such void geometrization can be called “fault-zone detached-and-fractured” (dendrite) [6, 7].

The profile of the described system will look like reservoir rocks development zones, alternating with the non-reservoir development zones. When the fissured-metasomatic limestones are adjacent underneath the limestones altered in the oil-gas bearing horizon of the contact zone, they will combine the uniform fracture-cavern-pore system. The most important is the fact that the extended spatially-fractured zones will combine the discreted areas for reservoir rocks development in oil-gas bearing horizon of the contact zone. It's necessary to mention that these areas occurred on the increased paleorelief. Generally, the fractured zones combine that sort of discreted areas into the uniform hydrodynamic system, through which both hydrothermal waters and fluids (oil and gas) can migrate.

Carbon-bearing platforms formation from Ordovician to the end of the Devonian

Beginning from the Ordovician period to the end of the Devonian in some areas of the West Siberia depression the carbonate formations accumulated sequentially and continuously, but somewhere else they accumulated occasionally.

In the first case the carbonate formations are not separated among themselves. They seem to be the uniform massif in the event of tectonic disturbance. This increases their overall potential for the reservoir rocks formation and future oil\gas fields occurrence. The characteristic feature of the sedimentation in Ordovician, Silurian and Early Devonian periods (Fig.2A, 2B, 2C), is the following. When correlating the extent area of the carbon-bearing platforms, it has been identified that they gradually decrease or increase.

The sedimentation pattern changed in the Middle Devonian period. When there was a certain decrease in the carbonate accumulation area in the central part of the West Siberia depression, a new, not very vast area of the carbonate rocks accumulation occurred (Fig.2D) in its western extreme point. In the Late Devonian period (Frasnian) the carbonate accumulation area was decreasing in the central part of the West Siberia depression, when the carbonate accumulation in the western area was increasing. At last, in the Late Devonian (Famennian), two areas became the uniform carbon-bearing platform. This expanded its borders along the territories where the carbonate accumulation processes had never occurred before.

4. Conclusion

1. Paleozoic carbonate rocks, producing carbon-bearing platforms on the West Siberia depression, were formed continuously from the beginning of the Cambrian to the end of the Carboniferous. This was the prolonged formation of the carbonaceous rock mass being either uniform or separated layers by the other rocks.
2. The crusts of weathering in the oil-gas bearing horizon of the contact zone were formed. These occurred along the pre-Jurassic surface as a result of Gertsynskaya folding processes followed by the continental stand of the area, and had the advanced

reservoir rock properties. During sedimentation in the sea of Jurassic-Paleogene period, the Paleozoic formations that had been altered by the hypergenesis processes underwent the secondary transformation of katagenesis processes (secondary katagenesis) which relate to the system of renovated faults.

3. Secondary-katagenesis processes of the fissured hydrothermal–metasomatic genesis through the carbonate formations resulted in the occurrence of the secondary-katagenesis reservoir rocks, being a zoneform of the reservoir rocks, alternating with the stationary zones of the non-reservoir rocks. Their superposition in the reservoir rock areas formed in the oil-gas bearing horizon of the contact zone created the uniform hydrodynamic system for oil and gas movement and oil-gas accumulations and fields.
4. The Ordovician, Silurian and Early Devonian witnessed the carbonate accumulation in the central part of the West Siberia depression boundaries. In the Middle Devonian along with the central zone there formed the isolated western carbonate accumulation zone. The central carbon-bearing platform area was reduced in Late Devonian (Frasnian), while the western one – expanded; they became convergent. The carbon-bearing platform was uniform in Late Devonian (Famennian); the carbon accumulation occurred along the vast territory of the West Siberia depression. The Carboniferous suffered the carbon-bearing platform area decrease, while the end of the period saw the carbon accumulation decline.

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