Influence of tectonic inversions on the process of tectonic development of the north part of the west Siberian oil and gas province

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Abstract: The article deals with the history of tectonic development of the territory of the northern part of Western Siberia. Particular attention is paid to the influence of alternating (inversion) tectonic movements on this process. The study presented in this article is based on paleotectonic analysis performed by the isopachian triangle method. As a result of the work carried out, the existence of tectonic inversions was established, which had a significant effect on the distribution of sedimentary strata and the tectonic structure of the northern part of the West Siberian sedimentary basin.

1. Introduction
The history of tectonic development in the northern part of Western Siberia is characterized as a complex process, influenced by a large number of different factors [1], [2], [3], [4], [5]. The most important of these, according to the authors, is the influence of alternating (inversion) tectonic movements.

Tectonic inversion is a change in the direction of tectonic movements within a single territory during geological time. As an example, one can cite a phenomenon when the uplift of a certain territory is replaced by a relative immersion, which is reflected in the plan as the transformation of the anticlinal forms of the paleo-relief into synclinal ones, and vice versa [6], [7].

Some researchers argue [8], [9] that zones of inversion tectonic development are favorable for the formation of oil and gas deposits. The identification of such zones, respectively, corresponds to the tasks of searching for new clusters of hydrocarbons. The relevance of the study, therefore, is to identify new potential areas of oil and gas accumulation, in order to maintain the resource base of hydrocarbons within the northern part of the West Siberian oil and gas province.

2. Research
In the course of the conducted research, the task was to identify the existence of tectonic inversions within the northern part of Western Siberia and to trace the change in their range during geological time. Identification of successive changes in the forms of the paleo-relief during the geological time associated with inversion tectonic movements is possible during paleotectonic analysis, which plays an important role in the structure of the study. At this stage of the work the authors set the task of qualitative evaluation of inversion tectonic movements, which is carried out by means of a complex interpretation of the results of paleotectonic analysis.
3. Results and discussion

3.1 A method for constructing paleotectonic maps

For the qualitative evaluation of alternating tectonic movements by the authors, according to the method of V.B. Neumann [10], a set of paleotectonic maps (isopachite maps) was compiled (Figure 1), describing the distribution of sedimentary strata in the Jurassic-Cretaceous development period of the northern part of the West Siberian oil and gas province.

The basis for constructing paleotectonic maps was the structural surfaces of the reflecting horizons A, B, M, M/ and G. Horizon A corresponds to the position in the wave field of the sole of the Mesozoic-Cenozoic sedimentary front. The other reflecting horizons correspond to the roofs of the Upper Jurassic, Neocomian, Aptian and Alb-Cenomanian sedimentary complexes, respectively.

According to the V.B. Neumann's methodology of paleotectonic studies, the difference between the maps A-B, B-M, M-M/ and M/-G characterizes the distribution of sediments accumulated at the end of the Jurassic, Neocomian, Aptian and Alb-Cenomanian times, respectively.

In order to characterize the processes of changing the direction of tectonic movements, for each of the paleotectonic maps, the authors identified the main (largest) tectonic elements characterizing the paleo-relief of the investigated territory at the corresponding moment of geological time. When distinguishing these structures, the features of modern tectonic zoning of the Mesozoic-Cenozoic sedimentary cover of Western Siberia [11] were taken into account, as well as regional peculiarities of changes in the thickness of sedimentary complexes. When carrying out paleotectonic zoning, the authors tried to preserve a certain continuity with the names of modern tectonic structures.

3.2 Analysis and interpretation of the results of paleotectonic constructions.

In the Jurassic time (Figure 1, a), over-Taymyr, over-Paykhoy-Yamal and over-Enisey paleomonoclysis and Yamal paleomegalithic bank were the most hypsometrically expressed in the Paleoplane positive structures. It should be noted that these tectonic elements experienced the predominant relative uplift during the entire Mesozoic-Cenozoic period. The thickness of the Jurassic sediments formed within these structures varies from 200 to 1600 m. The intermediate position at the considered time was occupied by the Yamal paleomegalithic bank and the Nadym-Variegan paleomonoclysis within the limits of which the thickness of the Jurassic sedimentary strata reached 1600-1800 m.

At this time, the individual elements of one of the most contrasting modern positive tectonic structures occurred - the Messoyahsky Paleomegalithic bank.

The largest negative structures at the end of the Jurassic period were Yamal-Gydan and Pur-Tazovo paleomegasineclises, as well as the West Yamal paleobasin. The above structures experienced the most intensive diving, as a result of which, the most powerful (1600-4000 m) thickness of Jurassic sediments formed.

Thus, in the Jurassic, downward tectonic movements covered the central and north-eastern parts of the study area, while the peripheral areas of the sedimentary basin and its southern part experienced relative uplift.
Figure 1. Paleotectonic maps of the north of Western Siberia in the Jurassic and Neocomian periods.

The first significant regional changes in the character of the tectonic development of the territory under consideration are recorded in the Early Cretaceous time (Figure 1, b). Its hypsometric expression was preserved by the over-Taymyr, over-Paykhoy-Yamal and over-Enisei paleomonoclay. At that time, the structures mentioned have been characterized by inherited relative uplift, which resulted in an increase in the size of the over-Paykhoy-Yamal and over-Enisei paleomonoclays.

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occurred that caused the dissolution and subsequent articulation of the western part of the Yamal-Gydan paleomegasineclise, the West Yamal paleobasin and the Yamal paleo-megalithic bank. As a result of the ascending tectonic movements to which the listed structures were subjected, a large inversion tectonic structure was formed, the Yamal paleomonoclysis within which sedimentation of the early Cretaceous age with the thickness from 600 to 1200 m took place. At the end of the Neocomian time, this structure conjugated the over-Taymyr and over-Paykho-Yamal paleomonoclay.

As a result of descending inversion tectonic movements, the expansion of the Pur-Tazovskaya paleomegasineclise to the south occurred. The thickness of the sediments accumulated within this structure during the Neocomian time reached 2,400 meters. The position of the main depocenter of this structure corresponds to the position of the Bolshekhtskaya cavity - the most contrasting negative structure of the northern part of the West Siberian plate.

Hypsometrically expressed in the Jurassic time, the Nadym-Variegan paleomonoclay located in the southern part of the study area significantly reduced its area due to the expansion of the over-Paykhoy-Yamal and over-Enisei paleomonoclay in the eastern and western directions, respectively. Also, this territory is characterized by a greater capacity of accumulated deposits, which indicates that the area experienced a more active dive in the Neocomian period, in comparison with the Jurassic period. The thickness of the Early Cretaceous sediments within the considered territory varies from 800 meters within a large part of the structure, up to 1500 m in individual depocenters.

Among the most significant moments of the Early Cretaceous stage of the tectonic development of the territory under consideration is the formation of Messoyakhsky paleomegalithic bank, which divided the Nadym-Pur-Taz and Yamal-Gydan paleomecasineclises. The activation of ascending tectonic movements is indicated by changes in the thicknesses of the Early Cretaceous (800-1300 m) and Jurassic (1600-2200 m) sediments within the structure under consideration.

Thus, the combination of ascending and descending inversion tectonic movements caused significant changes in the size and hypsometric severity of both positive and negative tectonic structures presented in the Paleorelief of the North West Siberian Plate during the Neocomian time. At the same time, when comparing maps of the Jurassic and Neocomian (Early Cretaceous) isopachites, transitions of positive forms of the Jurassic relief to negative in the neocomian were recorded, and vice versa - negative to positive ones.

The most significant transformations of the paleo-relief within the northern part of the West Siberian sedimentary basin occurred in the Aptian time (Figure 2, a). At this time, most of the study area was characterized by a predominance of ascending tectonic movements. One of the most significant transformations of the paleorelief, which occurred under the influence of activated positive vertical movements, was the articulation of the over-Taymyr and over-Enisey-Makhovskaya paleoanteclises, which led to the formation of massive over-Taymyr-over-Enisey paleomegaanteclise, occupying the entire eastern part of the study area. Within this structure, from 40 to 200 meters of Aptian sediments accumulates.

The second most important tectonic transformation that occurred in the Aptian period can be called the disbandment of the Messoyahsky Paleomegalithic bank. This structure, clearly distinguished in the Paleorelief of the Neocomian time, is not visible in the Paleorelief of the Aptian.

Significant changes occurred with Nadym-Pur-Tazovo and Yamal-Gydan paleomecasineclises. These negative structures, actively developing in the Jurassic and Early Cretaceous (Neocomian) time, as a result of the influence of inverse ascending tectonic movements, were partially connected between themselves and re-formed into intermediate forms of the paleorelief. So, in place of these structures, in the central part of the study area, the Nadym-Pur-Tazovo paleo-megaterrace was formed, where 200 to 500 meters of sediments accumulated.
Figure 2. Paleotectonic maps of the north of Western Siberia in the Aptian and Alb-Cenomanian periods.

The complete conversion of the Neocomian paleorelief, caused by the change in the regime of ascending movements to the immersion in the Aptian, occurred in the northwestern part of the West Siberian Plate, within which the Yamal paleomonomoclysis was transformed into the extensive Yamal-Gydan paleomegasincline. The thickness of the Aptian age deposits in this part of the study area is up to 840 meters, which makes it the most contrasting negative structure of that time.
In the Alb-Cenomanian time (Figure 2, b), most of the territory of the north of Western Siberia experiences intense immersion. Thus, a clear tectonic inversion is observed - active uplift in the aphthus is replaced by immersion in the Cenomanian. The north-western part of the investigated territory is most actively immersed. Yamalo-Gydan paleomegaantecline significantly increases its area, covering most of the territory of the Yamal and Gydan peninsulas, as well as the northern part of the Ob-Tazovo interfluve (the territory of the Semakovo, Yamburg and Severo-Urengoy fields). Such an area transformation allows us to name this structure as the Yamal-Gydan-Ob-Tazovo paleomegaantecline. Within this structure, from 800 to 1000 m of sediments are accumulated.

The central part of the Nadym-Pur interfluve also experiences an immersion. At this time, the authors distinguish here the structure of the intermediate type - the Nadym-Pur paleomegaantecline. This structure occupies an intermediate position between the actively submerged northern part of the sedimentary basin and its uplifting peripheral part. Here, 400-700 m of sediments accumulate.

Within the southern part of the territory of the Yamal-Nenets Autonomous District two major positive structures are distinguished: the Variogan-Purpei and Tagrinsky-Harampur-Russkaya paleomegaanteclises. Within them, the territory experiences relative growth. The thickness of sediments accumulating within these structures is estimated at 300-500 meters.

Ascending tectonic movements have already traditionally experienced the peripheral part of the territory under study. The over-Paykhoy-Yamal paleomegaanteclise, located in the west, is characterized by a reduced thickness of sedimentation, varying from 40 to 500 meters.

Over-Taimir - over-Enisey paleo-megamonoclysis at the end of the Cenomanian time is again divided into two separate positive structures - over-Taymyr paleomegaanteclise and over-Enisey-Makhovskaya paleomegaantecline. This happens due to a significant immersion caused by tectonic inversion within the territory of the modern Ust-Yenisei-Agap belt of mega-downwarps. Within the over-Taymyr and over-Enisey-Makhovskaya paleostructures, from 80 to 500 meters of sediments are accumulated.

4. Conclusion
Based on a comprehensive analysis of the results of seismic work, as well as exploration drilling data, the authors compiled regional paleotectonic maps at a scale of 1: 500,000, characterizing the main stages in the formation and development of the sedimentary basin in the Jurassic-Cretaceous period.

Based on the isopachite maps constructed, the authors identified large, regional tectonic structures that formed the face of the paleorelief of the northern part of the West Siberian Plate at the end of the Jurassic, Neocomian, Aptian and Alb-Cenomanian time.

The analysis of the constructed maps made it possible to identify and localize the regions of existence of inversion tectonic movements, and also to trace the transformation of tectonic structures in the course of geological time. In the course of the work it was established that during the Mesozoic period of the development of the area studied, the negative forms of the paleorelief changed to positive, and vice versa - positive forms passed into negative. Hence, such a transformation was not a local, but a regional phenomenon, covering the entire northern part of the West Siberian plate.

The most active effect of tectonic inversions during the Jurassic-Cretaceous period was experienced by the central and northern parts of the area under study. As is known, the main oil and gas content of the northern part of the West Siberian oil and gas province is just confined to the territory of the Nadym-Pur-Tazovo interfluve, as well as to the Yamal and Gydan peninsulas.

Thus, the territory of the Yamal Peninsula experienced two tectonic inversions - a partial immersion in the Jurassic was replaced by a rise in the Neocomian, then it was replaced by a dive that lasted during the Aptian-Albian-Cenomanian time.

The territory of the Gydan peninsula developed relatively successive, experiencing a predominant immersion in the Mesozoic. Hence, some parts of the peninsula periodically experience uplifting.

The territory of the Nadym-Pur-Tazovo interfluve was most actively affected by alternating tectonic movements. In the Mesozoic time, three tectonic inversions can be distinguished. In Jurassic
time, the territory under consideration experiences a predominant immersion, in the Neocomian, as a result of the change of signs of tectonic movements, the area of immersion of the territory increases significantly in a southerly direction.

Then, in the Aptian, there is a complete transformation of paleorelief - an active uplift of the territory takes place. In the subsequent Alb-Cenomanian geological era, the next major tectonic inversion occurs, entailing the immersion of the Nadym-Pur-Tazovo interfluve.

The inverse character of the development of the northern part of the West Siberian sedimentary basin, which caused a frequent change of ascending and descending tectonic movements, was accompanied by crushing and disturbing the continuity of sedimentary rocks, which are reflected in the formation of macro- and microcracking. The tectonically weakened zones were areas preferable for vertical jet migration of formation fluids. This becomes possible due to the reduction in the stress state of the rock massifs, which manifests itself in the form of a drop in both reservoir pressure and pore pressure, which makes these plots the most favorable for migration of fluids. Similarly, the existence of tectonically weakened zones can explain the movement of oil and gas in horizontal directions during the filling of traps.

The peripheral part of the investigated territory in the period under consideration experienced a predominant uplift and was deformed to a lesser degree than the central part of the basin, which makes them less promising for the localization of oil and gas fields.

Summarizing all the above mentioned, one can draw a conclusion about the influence of inversion tectonic movements on oil and gas potential at the regional scale. Inversion tectonic movements, according to the authors, predetermine the main directions of migration of hydrocarbon flows in deposits of the sedimentary cover.

The authors set a further task to develop a methodology that will allow a quantitative assessment of the effect of tectonic inversion movements on the sedimentary cover and on oil and gas potential. The methodology should allow the identification of new oil and gas-promising areas within the territory of the northern part of the West Siberian oil and gas province, which have not yet been tested by drilling.

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