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A New Approach to the Identification of Active Fracture Zones of Oil-Bearing Rocks Based on Satellite Images and GIS Technologies

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***Abstract*—Methodological issues of identifying active fracture zones as enhanced oil recovery zones using information-space technologies are considered. Because the insufficiency of seismic methods for identifying active fracture zones used landscape indicators of active fracturing zones, which are determined by the results of a joint analysis of seismic data and satellite images. To determine the landscape indicators, a summer satellite image of medium resolution (30 m.) Landsat was used. To identify landscape indicators of active fracture zones, the landscape features of the field territory were used, in particular, the directions of rivers and other watercourses, the rectangular shapes of the boundaries of the transition of wetlands to forest complexes, and others. The location of landscape indicators was used to confirm the identification of active zones of fracture by landscape indicators near a high-debit well in a satellite image. Other examples of interpretation of active fracture zones using the identified landscape indicators in a satellite image are presented.**

Keywords—seismic data, satellite images, active fracture zones, landscape indicators

I. INTRODUCTION

Due to the natural deterioration of the resource base of oil in Western Siberia as the main oil-producing region of Russia, hard recoverable reserves account for a growing share. The largest volume of these reserves is concentrated in reservoirs with low and ultralow filtration and capacitance properties (permeability, porosity of reservoir rocks). Both Lower Cretaceous and Jurassic layers developed in the territory of the Khanty-Mansiysk and Yamalo-Nenets Autonomous Districts are of the greatest interest. Due to low permeability of reservoir rocks and as a result of low well flow rates the main approach to development of hard-to-recover reserves is expensive technology of drilling horizontal wells with application of hydraulic fracturing. However, hundreds of wells drilled earlier in Western Siberia also have abnormally high flow rates, which specialists associate with active fracture zones of oil-saturated rocks. However, the existing geophysical methods of searching for oil-saturated fracture zones based on seismic data are still underdeveloped. The previously developed [1, 2] technology for detecting fracture zones using seismic data, which allows for their mapping, cannot distinguish tectonically active from inactive fracture zones.

Application of aerial photography and space images in interpretation of fault zones and developed by them fracture zones has a long history and is described in a great number of works [3-8]. However, the authors of the article are not aware of the works on revealing tectonically active fracture zones by means of seismic data and space images comparison. In this connection, a new approach to solving the problem is proposed, based on a combination of seismic exploration and landscape indications. Appearance of active fracture zones of on the ground surface should be displayed with the help of landscape indicators, as which are considered features of landscape settings. As far as we know, no methodological issues have been developed to define such indicators using space images.

In connection with the above-described purpose of the article was to develop methodological issues of defining landscape indicators of active fracture zones on the basis of space images and their use together with the results of fault network mapping using seismic survey data.

II. DETERMINATION OF LANDSCAPE INDICATORS OF ACTIVE FRACTURE ZONES USING SPACE IMAGES

As described above, modern geophysical methods do not allow to reveal tectonically active fracture zones. An approach based on the use of landscape indicators of active fracture zones, which can be detected using space images, can be considered promising for their detection. It is known [5, 9-11] that fracture active zones "breakthrough" to the Earth surface as a manifestation of geological faults in the form of gradient transitions of the Earth surface heights. Due to the fact that faults tend to deviate from the vertical (5-7º), their position on the surface shifts relative to the position at depth. As a result, the position of the landscape indicators will be shifted by 250 meters or more from the fault depth position. The use of aerial photography and space imagery methods in the interpretation of faults on the Earth's surface was previously considered in a large number of works [12-18]. High degree of swamping of the Western Siberia territory leads to the leveling of these relief features, which makes it difficult to interpret them using remote sensing data. In this connection it is proposed to use landscape indicators, which take into account not only relief features, but also transitions boundaries of natural complexes (forest or swamp vegetation, watercourses, etc.).

To determine landscape indicators of active fracture zones using space images we will analyze the connection of the mapped fracture zones using seismic data, i.e. fault network and landscape changes on the Earth surface. For these studies a summer space image of Landsat (spatial resolution of 30m) was chosen. The space image processing was performed using the ArcGis 10.3 geoinformation system.

Fig. 1 shows a fragment of the space image of the Sredne-Nazymskoye field territory (north-western part of KHMAO). The central part of the image fragment shows the location of exploration well #219, which was characterized by abnormally high oil flow rates from the rocks of Bazhenov-Abalaksky complex [19] and will be used by us as an indicator of rock fracture zones activity in close proximity to the well. The blue lines in the figure show a system of the faults mapped according to seismic data at a depth of 2400-2500 meters. Dark coniferous forests are shown on the image in green and dark green colors, mixed and small-leaved forests - in yellow, wetlands - in pink and clear water areas in black.

Analyzing landscape changes, it can be noted that the wetland channels of watercourses, as a rule, "adapt" to the active fracture zones, mapped according to seismic data [19]. It should be noted that sharp borders of crossings of forest complexes to wetlands, as well as watercourses and small rivers to wetlands, etc., will also be considered as landscape indicators of active fracture zones.

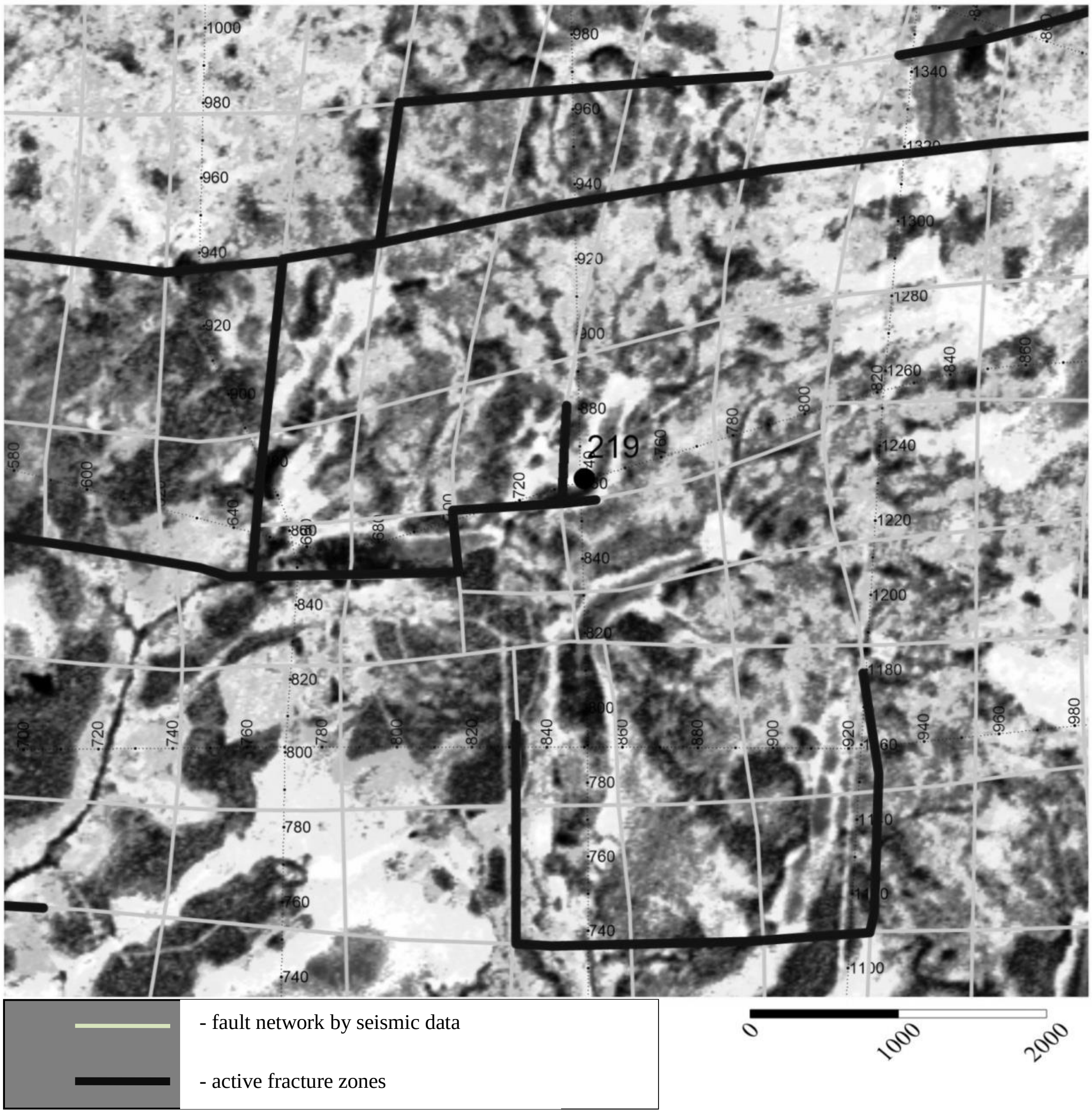
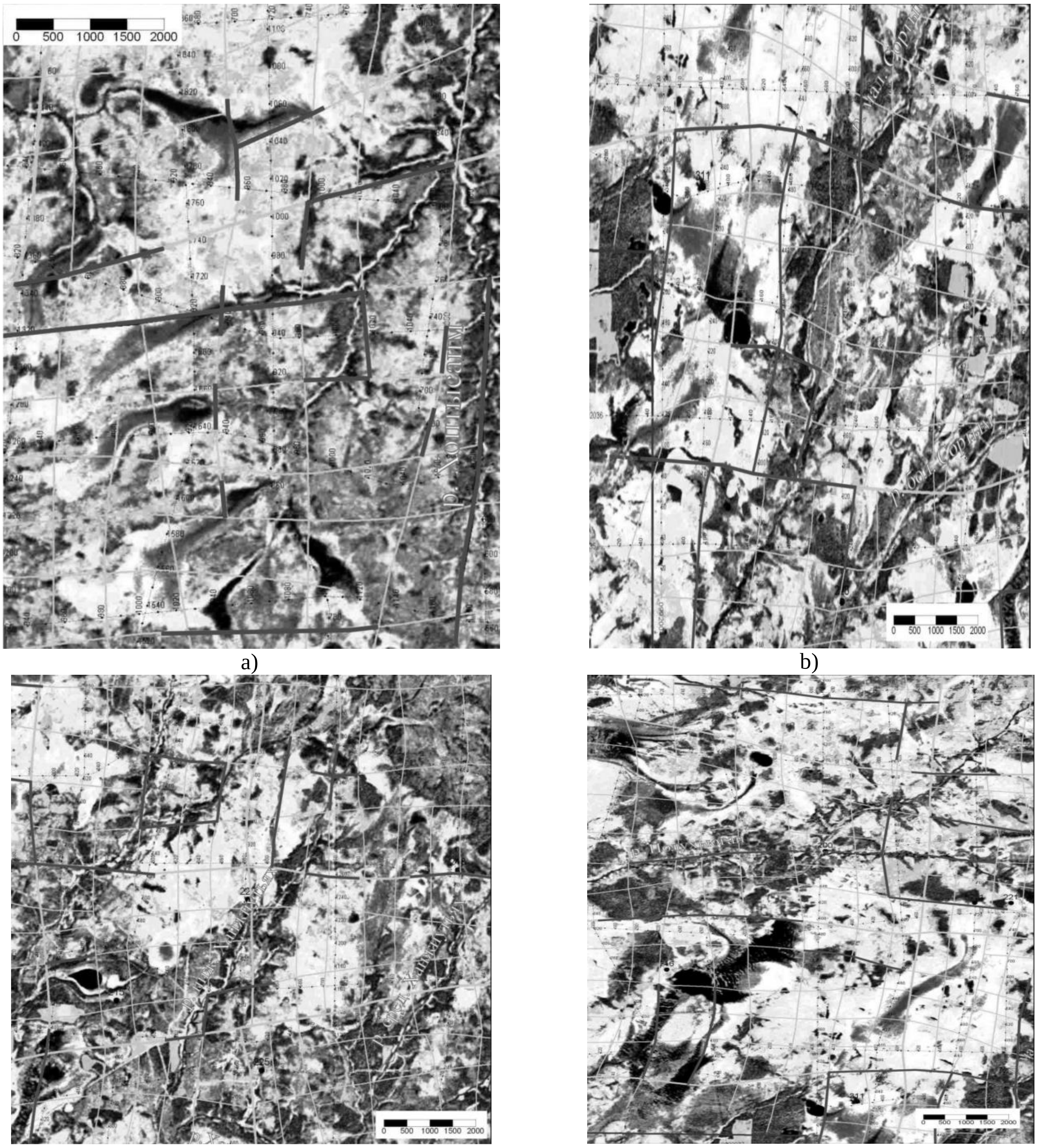


Fig. 1. A fragment of a space image with a network of geological faults and the location of a high-debit well

Using these landscape indicators, Fig. 1 shows with blue thick lines the elements of the fault network, which are located near the landscape indicators selected in the image. Consequently, we will consider the elements of the fault network marked in blue as locations of the active fracture zones. The location of the high-debit well 219 in the image near the blue lines (at a distance of approximately 100 meters) can be considered as a confirmation of this.

III. Application Of Landscape Indicators In Tasks Of Revealing Active Fracture Zones

With the use of the approach considered above, it will demonstrate the possibility of revealing the active zones of fracture-thickness in a number of other areas of this field using of landscape indicators. The light lines in the figure 2 show a system of the faults mapped according to seismic data at a depth of 2400-2500 meters, grey lines show the active fracture zones. Examples of the relationship between the location of river beds and the extension of fracture zones on the territory of the deposit are river bed areas, in particular, the Hoptysaim River (Fig. 2-a), which can be considered as landscape indicators of active fracture zones. Analysis of the space image fragment on Fig. 2-b showed that the Landscape indicator of fracture zones, as well as on the previous fragment, are sharp changes in river bed direction.



a) b) c) d)

Fig. 2 Examples of revealing the active fracture zones according to the results of complex analysis of seismic data and space imagery

Fig. 2-c and 2-d present fragments of space images showing that the active fracture zones control the borders of transition from swampy areas to forest complexes.

IV. Conclusion

A new approach to detection of active fracture zones as enhanced oil recovery areas is proposed, based on the results of joint analysis of seismic survey data and space images. The researches carried out on the oil-producing territory in conditions of essentially swampy settings, typical for Western Siberia, allowed to define landscape indicators of active fracture zones, in the quality of which the following characteristic features were used: direction of rivers and waterways flow, as well as rectangular forms of boundaries of transition from swampy areas to forest complexes, which, according to the authors, can be signs of faults activity, controlling fracture zones.

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